URBAN DEVELOPMENT: GUIDELINES FOR PROTECTION OF FISH HABITAT IN INSULAR NEWFOUNDLAND

Canada

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LGL LIMITED
environmental research associates

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PREFACE

This document was prepared by Mr. Dirk deGraaf of LGL Limited, Environmental Research Associates under a contract funded by the Habitat Research and Management Section, Department of Fisheries and Oceans, Newfoundland Region. Mr. Hugh Bain of the Habitat Research and Management Section acted as Scientific Authority for the contract and provided additional manuscript and editorial revisions.

During the preparation of the manuscript, Mr. deGraaf became aware of a common attitude among the people that he interviewed; that is, the impossibility of conserving fish habitat in an urban environment. However, viable fish populations in an urban setting are quite possible provided a reasonable degree of habitat protection is incorporated in the development plan.

The purpose of these guidelines is to provide a source of reference for individuals and organizations involved in urban development and maintenance whereby they may plan their activities in a manner compatible with the conception of fish habitat preservation. This document has been prepared to create an awareness of the salmonid fish resources of insular Newfoundland, to describe briefly the habitat required by these fish species and to compile the state-of-the-art techniques for preservation of this habitat. The use of technical terms has been avoided whenever possible to improve the readability of this report for individuals of widely different backgrounds.

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PURPOSE AND SCOPE

Fish habitat protection in Newfoundland falls under the jurisdiction of the Department of Fisheries and Oceans (DFO); therefore, all projects which have the potential to affect watercourses utilized by fish must be approved by DFO. These guidelines are intended to help developers incorporate provisions for fish habitat protection into development thus ensuring that fish and their habitat are not adversely affected by the implementation of the project. Whenever the techniques proposed in these guidelines are not practical within the framework of a specific development, the developer or agency should contact personnel of the Department of Fisheries and Oceans early in the planning stage to develop a site-specific plan for habitat protection. Since all proposed works or undertakings which may affect fish habitat will require prior authorization by the Department of Fisheries and Oceans, planners, engineers, and contractors of any development that may affect fish habitat are advised to contact DFO at an early stage to determine the actual procedures required.

This document has been prepared for the use of individuals having little or no background in fisheries biology or habitat requirements of fish. The freshwater fish resource of Newfoundland is discussed and simplified life histories of stream-resident trout is presented in order to acquaint the reader with the habitat requirements of a fish salmonid population. The Fisheries Act and the Newfoundland Fishery Regulations are included with explantory notes to explain the relevance of specific regulations regarding habitat protection in urban development. The actual guidelines have been presented with a minimum of discussion and literature review. In some instances, additional discussions and a brief literature review have been appended to provide the reader with greater detail. Individuals requiring further information should consult references listed in the Technical Bibliographies.

FRESHWATER FISH RESOURCE

The freshwater fish resource of Newfoundland is unique among areas of comparable latitude in North America since salmonids are the predominant species in virtually all waterbodies. Of the 23 fish species listed for insular Newfoundland by Scott and Crossman (1964), only two, namely the Atlantic salmon (Salmo salar) and brook (mud) trout (Salvelinus fontinalis), are widely distributed. Brown trout (Salmo trutta) have become locally abundant in many watercourses on the Avalon Peninsula, occasionally to the virtual exclusion of native brook trout (Nyman 1970). Rainbow trout (Salmo gairdneri), like the brown trout, were introduced into Newfoundland in the late 1800's (Scott and Crossman 1964). Today, this species is restricted in its distribution to a few watersheds in the vicinity of St. John's and to Lower Shoal Harbour and Shoal Harbour Rivers near Clarenville. The latter river also contains a small run of the anadromous form of rainbow trout, namely, the steelhead trout. This anadromous form has been occasionally caught in the Serpentine River and some of the Bay St. George drainages. A few other species, notably eels (Anguilla rostrata) and sticklebacks (Apeltes quadracus,

pungitius), are present in many river systems while Gasterosteus wheatlandi and Pungitius pungitius also occur in brackish water. Likely due to the low species diversity, the density and biomass of salmonids present in Newfoundland rivers tends to be higher than in most comparable mainland rivers. Also, they are able to utilize all habitat types and virtually every permanent body of water, whether standing or moving, supports a viable trout population.

The species most commonly affected by urban development are brook trout and brown trout. Generally, Atlantic salmon have been eliminated from small urbanized streams although they remain in some of the large rivers that pass through urban areas. Their elimination from smaller streams is likely due as much to angling and poaching pressure as to habitat-related factors. Sea-run forms of both brook trout and brown trout remain in many urbanized watercourses provided suitable spawning and rearing habitat remains accessible.

In order to maintain stocks of both resident trout and sea trout within a watershed, habitat protection is required for streams and ponds of all sizes. Since salmonids are the predominant species in insular Newfoundland, competition with other fish species for food and habitat is virtually non-existent. As a result, the various life-stages of brook trout, brown trout and salmon occupy habitats not normally used by these same species on the mainland. This means that in Newfoundland, small streams (i.e. even 2 m wide or less) are very important as fish habitat; in fact, much of the successful trout spawning in many watersheds occurs in small tributary streams. Ample rainfall and an abundance of bog-lands impart a relative stability to the flow in small streams ---a condition which is directly related to the "health" of a population in terms of its productivity.

The presence of good habitat (Plate 1) is instrumental in maintaining fish populations in a watershed. In the Rennie's River system within urban St. John's, the density of brown trout occupying an undisturbed section of the river was recorded as 63 g/m^2 (pers. comm., R. J. Gibson, DFO, St. John's). A standing stock in similar habitat within the Virgina River (St. John's) was 50 g/m^2 and consisted of 550 young-of-the-year and 140 older trout in an area of 348.61 m^2. The mean length of the older trout was 20.8 cm. Other areas in these rivers which have been channelized or otherwise severely disturbed (Plate 2), yielded much lower standing stocks. Perhaps more significantly, fry were absent in many of the more disturbed areas, suggesting that there had been no successful spawning in these areas.

Life History of Stream-Resident Trout

In order to understand habitat requirement, it is necessary to have a basic understanding of the life history of the species involved. Most salmonids in Newfoundland waters have somewhat similar habitat requirements; therefore, for the purpose of this document, the life history of a generalized trout will be described. Rainbow trout which differ from other salmonids in Newfoundland in their spawning and hatching times and which are restricted in their distribution will not be considered in this generalized description.

Plate 1. Excellent fish habitat. Bank vegetation provides good cover and channel slope is conducive to pool formation.

Plate 2. Poor fish habitat. Development has encroached on channelized streambanks

Spawning for most Newfoundland trout occurs between late September and mid-November. Typically, eggs are laid in a depression (redd) which has been dug in clean gravel by the female. The location of the redd is selected by the female according to gravel size (ranging from 'pea size' for small trout to 'fist size' or greater for larger salmon and sea trout). Actual spawning takes place following an elaborate ritual and then the eggs are buried by the female.

The eggs remain in the gravel over winter and hatch in March or April. The young 'alevins' remain within the gravel, feeding on their yolk sacs, and emerge in late April or May. The young trout then disperse up- and downstream, most typically occupying the edges of the river and shallow riffle habitat where water velocities are slower and where they find cover in the small spaces between the cobbles and pebbles. Most concentrations of these young-of-the-year will be situated near the spawning grounds. The young trout feed primarily upon insects and other small aquatic animals. Feeding occurs primarily during daylight hours and prey are located by sight. As the fry grow, their habitat requirements change and they move into deeper water and among coarser rocks. Juvenile trout frequent a wide range of habitat types but need protective cover such as deadfall, undercut banks and overhanging brush. In order to achieve optimal growth and survival, these juvenile fish move up- and downstream seeking more favourable temperatures and food supplies. During the winter these small trout reduce activity by concentrating in deeper, slower water or by taking cover in coarse substrate.

Adult trout also require cover, both in the stream and from overhanging vegetation. In absence of abundant cover these larger fish are restricted to a few deep pools; however, if sufficient 'escape cover' is present, they will utilize a wide range of habitat types. Adult fish also move considerable distances within a network of small streams, concentrating near good spawning habitat in fall and in deep pools or ponds during the winter then scattering widely to utilize the best feeding areas during spring and early summer. As water temperatures rise in mid-summer, brook trout tend to concentrate again in ponds or areas where groundwater upwellings keep the water cool whereas brown trout usually remain in streams. Above 18°C, the activity of brown trout increases whereas that of brook trout decreases. This partially explains why brown trout out compete brook trout in some watersheds.

Both adult and juvenile trout will eat a wide variety of foods, including both aquatic invertebrates and terrestrial insects which fall into the stream. In many small streams the latter provides a very important proportion of the total diet. It is therefore important for the well being of a trout population to maintain a diversity of habitat for all life history stages of the fish. Specific habitat types include riffles and pools for different sizes of trout, spawning gravel, coarse gravel which provides habitat for aquatic invertebrates, and stream-side vegetation which provides cover, shade and a source of food in the form of insect drop-off. Due to the hydrological and topographic characteristics of most watersheds, all these habitat requirements cannot be satisfied by one reach of a watercourse; therefore, fish of all size classes must be able to move between various stream reaches.

HABITAT ALTERATION

Stream habitat may be altered by virtually any development activity within the watershed. Changes in the hydrological regime due to increased runoff rate may affect habitat by changing the depth and velocity of the stream which in turn may change the rates of erosion or deposition. The addition of large quantities of fines (silt and sand) to a stream may result in the sedimentation of pools and riffles thereby destroying spawning habitat and cover for fish. The sustained addition of very fine material such as fine silt/clay will increase the turbidity of the stream and possibly decrease stream productivity. Changing the alignment of a watercourse by channelization or diversion will usually reduce the amount of fish habitat available and lower the quality of the remaining habitat.

Most of the development-related habitat alterations fall into at least one of three categories; water quality, water quantity, or stream alteration. Although these categories are frequently interrelated, they will be separated for the purposes of discussion.

Water Quality

The quality of water in a stream is determined by the concentration of various impurities present compared to the maximum allowable amounts for a given purpose. These allowable concentrations are governed by a variety of regulations administered by provincial authorities and are beyond the scope of these guidelines. However, under the terms of the Fisheries Act, water quality may not be impaired to the point where it adversely affects fish habitat.

Various pollutants enter urban waterbodies from a wide variety of sources, the most common being:

1. surface runoff from industrial areas,

2. direct discharge of industrial waste to watercourses or storm sewers, and

3. cross-over between sanitary and storm sewers.

Many substances, although not present in sufficient quantity to eliminate resident fish populations, may taint the fish to the extent that they become either unpalatable or unsafe for human consumption. Moreover, they may exert sub-lethal effects such as reducing the amount of food organisms, lowering the level of dissolved oxygen, and placing the fish under stress which has the overall effect of discouraging fish from populating otherwise good habitat.

In order to prevent deleterious substances from entering watercourses, all industrial discharges should be directed into the sanitary sewer system or retained in holding tanks for disposal by acceptable means. Likewise, whenever surface runoff or industrial washings are likely to contain toxic materials they should be directed to the sanitary sewer system or a liquid waste disposal system rather than storm sewers. In those instances when runoff is too large

for sanitary sewer capacity, mechanical separators or settling basins should be installed where most of the pollutants could be removed either by normal sedimentation or by the use of flocculating agents (e.g. alum). Individuals requiring specific designs for settling basins should consult the Technical Bibliography.

Sewage from urban areas can be a major source of impact on streams and lakes. If large amounts of sewage enter a stream or lake the high oxygen demand of the decomposing effluent may render the waterbody uninhabitable for fish. Smaller amounts of sewage will foster abnormally high growth of algae; under certain conditions of temperature or daylight the algae may die and cause an oxygen demand which could result in a fish kill.

In order to prevent potential problems arising from sewage pollution in urban areas, proper separation of sanitary and storm sewers should be maintained such that no untreated sanitary effluent is discharged directly and untreated into a freshwater system. At least primary treatment should be provided in all urban areas where sanitary sewage cannot be discharged directly into saltwater. In such cases, at least secondary treatment of sanitary sewage is also recommended.

Siltation, although traditionally treated as an aspect of water quality is closely interrelated with both water quantity and stream alterations. Silt may enter streams from a wide variety of sources; the most common sources are:

1. runoff from disturbed land during and after construction,

2. instream work with heavy equipment, and

3. storm sewers.

The effects of silt on fish and fish foods are well documented in the scientific literature. The impact is directly related to the amount of sediment, the nature of the sediment which enters the stream, the flow in a stream, the time of year and the duration of sediment load. The amount of sediment in the water may be reported as:

Total suspended solids -- determined by filtering a known volume of water and measuring the dry weight of the material on the filter paper.

Turbidity -- the optical property resulting from impurities in the water (including silt) which cause light to be scattered or absorbed rather than transmitted in a straight line.

Bed load -- the amount of sediment moving along the bed of the stream. This would be a more meaningful measurement but is rarely taken since it requires more sophisticated equipment than the above.

Increased sediment in streams may affect fish both directly and indirectly. Direct mortality by suffocation due to silt clogging gill surfaces

or from extreme stress caused by hyperventalation is a rare problem and will occur only under the most severe circumstances.

Indirect effects of sediment on fish resulting from loss of habitat and food supply are much more common than suffocation. Most of these indirect effects are caused by sustained high turbidity and sediment leaving suspension resulting in its deposition on the substrate. If high turbidity is sustained for several days (more than 4 or 5) during the spawning season, it may severely disrupt salmonid spawning activities since most Newfoundland species spawn during daylight hours and depend exclusively upon visual stimuli for successful reproduction. During other seasons of the year, sustained high turbidity will impair the feeding efficiency of resident salmonids and, in the long term, adversely affect growth and survival. Suspended sediments can also damage the breathing organs of aquatic invertebrates or clog their feeding apparatus resulting in a loss of these organisms and ultimately, a reduction in the food supply of local salmonids. Settled on the stream bottom, sediments fill in rearing pools, reduce intra-gravel flow in spawning areas, and suffocate the eggs of both fish and aquatic invertebrates.

The deposition of suspended sediments on stream bottoms normally occurs when water velocity decreases to a point where it can no longer transport the sediment in suspension. Transport velocities of some particle sizes are listed in Table 1. Most of the siltation or sedimentation problems arise from particles in the size range of fine sand to silt (0.25 - 0.005 mm). Finer materials, including clays, are very slow to leave suspension (up to 200 days) and normally cause minimal short term effects on stream fishes; however, they may cause a considerable decrease in water clarity. If a large plume of clay is discharged into a lake or pond, it will decrease the light penetration and production of food organisms for resident fish. Reduced visibility may also affect the feeding success of fish, especially if sustained inflows of fine materials maintain a high turbidity for an extended period.

Table 1. Transport velocities for various sizes of streambed materials (adapted from Fisheries and Oceans et al. 1980).

Material	Size (mm)	Transport Velocity
Silt	0.005 - 0.05	15 - 30 cm/s
Sand	0.25 - 2.5	30 - 65 cm/s
Gravel	5.0 - 15	80 - 120 cm/s
Pebble	25 - 75	140 - 240 cm/s
Cobble	100 - 200	270 - 390 cm/s

In most instances, the deleterious impact of silt can be mitigated by installation of simple settling basins or sediment traps at the outlfow of work sites or by construction practices which will minimize the time that soil is bare of vegetation. The size of settling basins required to remove average

silt particles from the runoff of a specific job site is based upon the peak anticipated runoff from a one-year storm and the settling rate of mean silt particles.

In some areas of Newfoundland marine clays are an important constituent of the soil. These particles will not be removed by standard settling basins; therefore, alternative methods such as the use of flocculants should be explored if a major problem is apparent. Sediment basins and other means of minimizing siltation as applied to specific construction practices will be discussed further in later sections of this document.

Water Quantity

The urbanization of a watershed affects the entire hydrological cycle. In short, an urbanized stream will react more swiftly to rainfall and will flood more rapidly than a forested or otherwise undeveloped watershed. Moreover, the baseflow of the stream during dry weather will decrease as a result of poor water storage in urbanized watersheds. This problem may become especially severe if unrestricted development occurs on hilltops and slopes, thereby preventing normal recharge of the groundwater aquifers. The effects of urbanization on the hydrological response of a watercourse are compounded by:

1. drainage of ponds and bogs to provide additional land for development,

2. channelization of headwater regions, and

3. construction of large impervious surfaces such as parking lots and roof tops.

Drainage of ponds and wetlands decreases the ability of a watershed to store water and therefore increases the severity of both floods and droughts on the flow patterns of a basin. Stream channelization in headwater regions compounds these effects by greatly increasing the rate of runoff; the result may be severe flooding and erosional problems in previously developed areas downstream. Thus, the creation of large impervious surfaces yields rapid runoff which may produce flooding downstream; baseflow is also decreased due to reduced infiltration. These effects may be partly mitigated by construction of holding tanks or soakage pits (see Figure 10). This problem will be discussed further in Section 3.1 of the Guidelines.

Stream Alteration

Stream channelization and diversion are the most severe forms of habitat alteration prevalent in Newfoundland urban streams. Many developments in major cities or towns have included channelization of whatever streams are present. In the past, since development was generally along the coast, channelization was normally restricted to the lowest reaches of the watercourse. As a result, overall impact was minimal since fish populations could be maintained by spawning and rearing habitat located farther upstream. In the urban centres of the province, extension of urban development and channelization in upstream

areas has the potential to negatively affect fish production as well as to produce flooding problems associated with accelerated runoff. Straightening and deepening natural stream channels decreases the amount of habitat present for both fish and their food supply, aquatic invertebrates. By increasing the slope of the drainage, current velocities are increased and this subsequently prevents deposition of gravel bars which are essential for successful spawning by salmonids.

Removal of stream bank vegetation: (1) increases the likelihood of bank erosion and stream sedimentation, (2) removes cover used by fishes to avoid predation, (3) increases the exposure to the sun which in some areas may result in water temperatures that are too high to support trout during the summer season, and (4) removes a supply of food for fish (both directly in form of terrestrial insects and indirectly in form of a litterfall which sustains some aquatic insects).

A final problem related to stream alteration is the construction of various structures across the streambed which may prevent movement of fishes between spawning areas and habitat used during other seasons of the year. The most obvious structures of this type are dams and improperly installed or otherwise inadequate culverts.

LEGISLATION

Section 91(12) of the British North America Act gives the Government of Canada exclusive legislative responsibility for coastal and inland fisheries. Fish and marine mammal resources and their habitats are protected from the effects of man-made disturbances primarily in accordance with Sections 20, 24, 27, 28, 30, 31 and 33 of the Fisheries Act and various regulations made under authority of Section 34 of the Act. In the Province of Newfoundland and Labrador, the Fisheries Act and its associated regulations are administered by the Department of Fisheries and Oceans.

Of note, are the powers of the Minister of Fisheries and Oceans under Sections 31 and 33 of the Act. Under Section 31, any work or undertaking which may affect fish habitat must be authorized by the Minister. In addition, Section 33.1 empowers the Minister to request specific information including plans, specifications, studies, procedures, and analyses related to the work.

Procedures for obtaining approval for work affecting fish habitat have recently been changed to a formal application and authorization system, further details of which are presented in Appendix 1.

THE FISHERIES ACT

Those sections of the Fisheries Act which apply to fish habitat protection are as follows:

Section 2: Interpretation

"fish" -- includes shellfish, crustaceans and fish eggs or spawn and juvenile stages of fish, shellfish and crustaceans.

"Minister" -- means the Minister of Fisheries and Oceans.

Section 20: Construction of Fishways

20 (1). "The Minister may require the construction and maintenance of an acceptable fishway around any slide, dam or other obstruction across or in any stream. If a fishway is not feasible, the Minister may require payment of sums of money to construct and operate a hatchery which would maintain the annual return of migratory fish."

(2). "The location design and capacity of the fishway must be approved by the Minister prior to construction. Subsequent to completion, it must be inspected and if necessary modifications performed by the owner."

(3). "Sufficient water shall be supplied for efficient operation of the fishway."

(4). "The Minister may authorize payment of one-half the cost of a fishway subsequent to its completion."

(5). "The Minister may authorize entry to property to construct a fishway and may recover the necessary costs of labour and material from the owner."

(6). "The Minister may order the removal of unused dams, slides or other obstructions at the expense of the owner."

(7). "The Minister may require construction and maintenance of fish steps or diverters up or downstream of a slide, dam or other obstruction to enhance the effectiveness of fishways."

(8). "The Minister may require the owner of a dam to provide sufficient flow over spillways to permit unimpeded descent of fish."

(9). "The owner or operator of any slide, dam or obstruction shall make provision for passage of migratory fish during the period of construction."

(10). "The owner or operator of any slide dam or other obstruction shall spill sufficient water into the riverbed below to ensure the survival of fish and fish eggs.

-- Dams in urban areas may be used either to create ponds for recreational or flood control purposes or to divert water for out of stream purposes such as swimming pools, ornamental ponds, or municipal water supplies. In all cases the above regulations pertaining to fish passage and adequate spills apply.

Section 24 (1)

"One-third of the width of any river of stream, and not less than two-thirds of the width of the main channel at low tide, in every tidal stream shall be always left open, and no kind of net or other fishing apparatus, logs, or any material of any kind shall be used or placed therein".

-- This regulation also applies to blockage of a stream during the construction of any bridge, culvert or any stream crossing.

Section 27

"No one shall erect, use or maintain in any of the waters of Canada whether subject to any exclusive right of fishery or not, any net, weir, or other device that unduly obstructs the passage of fish; and the Minister or any fishery officer may order the removal of or remove any net, weir, or other device that, in the opinion of the Minister or any fishery officer, unduly obstructs the passage of fish".

-- In the urban development context, this Section applies to poorly constructed culverts or other stream crossings.

Section 30

"No person shall destroy fish by any means other than fishing except as authorized by the Minister or under regulations made by the Governor in Council under this Act".

-- Fish in this context includes fish eggs.

Section 31

(1) "No person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat."

(2) "No person contravenes subsection (1) by causing the alteration, distruption or destruction of fish habitat by any means or under any conditions authorized by the Minister or under regulations made by the Governor in Council under this Act."

(3) "Every person who contravenes subsection (1) is guilty of an offence and liable

(a) on summary conviction, to a fine not exceeding five thousand dollars for a first offence, and not exceeding ten thousand dollars for each subsequenty offence; or

(b) on conviction on indictment, to imprisonment for a term not exceeding two years."

(5) "For the purposes of this section and sections 33, 33.1 and 33.2, 'fish habitat' means spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes".

Section 33

(1) "No one shall deposit ballast, coal ashes, stones or other prejudicial or deleterious substances in any river where fishing is carried on."

-- In urban areas fishing means angling.

(2) "Subject to subsection (4), no person shall deposit or permit the deposit of a deleterious substance of any type in water frequented by fish or in any place under any conditions where such deleterious substance or any other deleterious substance that results from the deposit of such deleterious substance may enter any such water".

-- In urban areas this may include materials discharged into a storm sewer which discharges directly into fish habitat or runoff from industrial sites which may contain deleterious substances.

33 (4) "No person contravenes subsection (2) by depositing or permitting the deposit in any water or place

(a) of waste or pollutant of a type, in a quantity and under conditions authorized by regulations applicable to that water or place made by the Governor in Council under any Act other than this Act; or
(b) of a deleterious substance of a class, in a quantity or concentration and under conditions authorized by or pursuant to regulations applicable to that water or place or to any work or undertaking or class thereof, made by the Governor in Council under subsection (13)."

(5) "Any person who contravenes any provison of

(a) subsection (1) or (3) is guilty of an offence and liable on summary conviction of a fine not exceeding five thousand dollars for a first offence, and not exceeding ten thousand dollars for each subsequent offence; or

(b) subsection (2) is guilty of an offence and liable on summary conviction to a fine not exceeding fifty thousand dollars for a first offence, and not exceeding one hundred thousand dollars for each subsequent offence."

33 (6) "Where an offence under subsection (5) is committed on more than one day or is continued for more than one day, it shall be deemed to be a separate offence for each day on which the offence is commited or continued."

(7) "Where a person is convicted of an offence under this section, the court may, in addition to any punishment it may impose, order that person to refrain from committing any further such offence or to cease to carry on any activity specified in the order the carrying on of which, in the opinion of the court, will or is likely to result in the committing of any further such offence or to take such action specified in the order as, in the opinion of the court, will or is likely to prevent the commission of any further such offence".

(8) "In a prosecution for an offence under this section or section 33.4, it is sufficient proof of the offence to establish that it was committed by an employee or agen of the accused whether or not the employee or agent is identified or has been prosecuted for the offence, unless the accused establishes that the offence was committed without his knowledge or consent and that he exercised all due diligence to prevent its commission".

33 (9) "Notwithstanding that a prosecution has been instituted in respect of an offence under this section, the Attorney General of Canada may commence and maintain proceedings to enjoin any violation of any provision of this section."

(10) "If a deleterious substance is spilled or dumped into fish habitat without authorization of the Minister the person or persons repsonsible are subject to prosecution".

(11) "For the purposes of this section and sections 33.1 and 33.2, 'deleterious substance' means

(a) any substance that, if added to any water, would degrade or alter or form part of a process of degradation or alteration of the quality of that water so that it is rendered or is likely to be rendered deleterious to fish or fish habitat or to the use by man of fish that frequent that water, or

(b) any water that contains a substance in such quantity or concentration, or that has been so treated, processed or changed, by heat or other means, from a natural state that it would, if added to any other water, degrade or alter or form part of a process of degradation or alteration of the quality of that water so that it is rendered or is likely to be rendered deleterious to fish or fish habitat or to the use by man of fish that frequent that water, and without limiting the generality of the foregoing includes

(c) any substance or class of substances prescribed persuant to paragraph (12) (a),

(d) any water that contains any substance or class of substances in a quantity or concentration that is equal to or in excess of a quantity or concentration prescribed in respect of that substance or class of substances pursuant to paragraph (12) (b), and

(e) any water that has been subjected to a treatment, process or change prescribed pursuant to paragraph (12) (c); 'deposit' means any discharging, spraying, releasing, spilling, leaking, seeping, pouring, emitting, emptying, throwing, dumping or placing;"

-- This includes unintentional deposits which may include materials washed into a watercourse by runoff water

" 'water frequented by fish' means Canadian fisheries waters."

-- All waters are covered unless absence of fish is proven beyond reasonable doubt.

33 (14) "Persons authorized to deposit deleterious substances into a watercourse may be required to

(a) conduct sampling, analyses, tests, measurements, or monitoring,

(b) install or operate equipment to comply with above procedures

(c) report such information (to the Minister)."

Section 33.1

(1) "Every person who proposes to carry on any work or undertaking that is likely to result in

(a) the deposit of a deleterious substance in water inhabitated by fish (either directly or indirectly),

(b) the alteration, disruption or destruction of fish habitat shall on request of the Minister provide the Minister with plans, specifications, studies, procedure, schedules, analyses, samples or other information relating to the work and with an acceptable evaluation or study of the water place or fish habitat which may be affected. Information supplied should be sufficient to determine

(c) whether the amount of deleterious substance deposited would seriously affect fish populations and what measures would be required to mitigate this impact."

NEWFOUNDLAND FISHERY REGULATIONS

The fish habitat sections of the Newfoundland Fishery Regulations are presently being amended. The changes being contemplated which are listed below should be in effect by 1983.

Section 26

(1) "For the purposes of subsection 31(2) of the Act, authorization, to carry on any work or undertaking must be obtained by submitting an application, in the form as set out in Schedule XI and available from the Department to the Department not less than 30 days prior to the proposed starting date."

(2) "To support an application made under subsection (1), the Department may require an applicant."

(a) to submit such further materials, information or reports in addition to that included in the application form as may reasonably be regarded as relevant, and

(b) to file with the Department an affidavit or statutory declaration verifying the particulars given."

(3) "An application from a body corporate shall be signed on behalf of that body by a person who in accordance with the regulations governing the conduct of that body is ordinarily empowered to sign documents on behalf of the body."

(4) Where an application contains false or fraudulent statement, or where materials, information or reports required or requested pursuant to subsection 33.1(1) of the Act have not been supplied, the application to carry on any work or undertaking will not be approved".

Section 27

(1) "For the purposes of subsection 31(2) of the Act, authorization to carry on any work or undertaking may be in the form as set out in Schedule XII and shall be issued by the Department upon approval of the application made under section 26."

(2) "Where there has been a violation under paragraph 33.4(1)(d) of the Act or where authorizatin has been obtained by means of a false or fraudulent statement or by supplying false information, the Minister or a Regional Director General may suspend or cancel the authorization."

27.1 "Where an authorization form has been issued under subsection 27(1), the person authorized shall keep the authorization at the location of the work or undertaking and shall produce it for inspection upon demand of an inspector or a fishery officer."

27.2(1) "For the purposes of subsection 31.1(1) of the Act, every person shall without request provide the Minister with the materials and information enumerated in that subsection."

(2) "The materials and information required by subsection (1) shall be provided in application for authorization in the manner and circumstances set out in section 26."

27.3(1) "For the purposes of subsection 33.1(2) of the Act, an order made under that subsection

(a) may be in writing or orally but if orally shall be confirmed in writng within 24 hours,

(b) shall be delivered to the person named therein or if that person can not conveniently be found it may be left with any person found to be in charge of the work or udnertaking,

(c) shall be posted at the location of the work or undertaking, if such a location then exists, and

(d) shall take effect immediately and remain in effect until the requirements of the order have been met."

(2) "No person shall remove or otherwise interfer with an order posted under this section".

Section 28

"In Canadian fisheries waters adjacent to the Province and in inland waters, no person shall use any explosives for any purpose unless authorized in the manner provided for in sections 26, 27, 27.1 and 27.2".

Section 29

(1) "No person shall deposit or otherwise dispose of any waste material

(a) in any inland waters or on ice over such waters

(b) in any harbour, cove or inlet or on ice over any harbour, cove or inlet in the coastal waters of the Province, or

(c) on any beach in the Province below the high water mark.

(2) "For the purpose of subsection (1), waste material includes refuse, garbage, rubbish, litter, scrap and discarded material of all kinds which are dumped, discarded, abandoned or otherwise disposed of".

FISHWAYS OBSTRUCTIONS REMOVAL REGULATIONS

Section 2: Removal of Obstructions

"Where the Minister of Fisheries for Canada is satisfied that any natural or casual obstruction existing in any waters frequented by fish, whether navigable or non-navigable, is intefering or is likely to interfere with the free passage of fish, he may cause such obstruction to be released, removed or destroyed, in whole or in part, in such manner and by such means as he deems advisable."

HABITAT PROTECTION GUIDELINES

1.0 STREAMSIDE DEVELOPMENT

The aesthetic attraction of streamside and lakeside properties, as a general rule, render this type of environment more attractive than otherwise similar lands (Pates 3, 4). This aesthetic appeal is enhanced by the presence of a viable trout population within the waterbody and the obvious recreational value of this resource. Historically, urban streams have been under utilized for recreation, since an abundance of rivers and ponds (all supporting trout populations) are within easy driving distance of all urban centres. As a result, urban watercourses and their fish have been disregarded as development has progressed. However, as the urban areas of the province grow and transportation costs increase it is likely that streams and ponds within the urban centres will become more important as recreational areas. Some major urban centres elsewhere, most notably in the U.S., have begun to expend considerable effort and expense to restore watersheds and fish populations for the benefit of residents (Leedy et al. 1981). In Newfoundland, we have the opportunity to maintain an urban fishery for wild trout, which would be impossible in most other locations.

In order to preserve both the aesthetic appeal of a stream or lake and the recreational appeal of its trout population, within an urban setting, habitat protection is required.

1.1. Buffer Strips and Greenbelts

Any radical departure from the natural stream-channel is likely to reduce trout production. The ideal type of habitat protection involves maintenance of buffer strips along the banks of the natural stream to preserve fish habitat with as little disruption as possible (Plates 3, 4). The width of the buffer zone required is variable and related to the size of the stream. A more detailed dicussion of buffer strips is presented in Appendix 2. Most streams in Newfoundland fall into two categories: (1) well-defined streams with stable banks dominated by either bedrock or coarse morrainal deposits, and (2) poorly defined drainages meandering through bog areas.

1.1.1. Well-Defined Watercourses

Guidelines

a. A buffer strip of five stream widths to a maximum of 10 m on either side of the high water marks of the watercourse should be left in its natural state (Figure 1).

b. If a steep or unstable bank is present on one or both sides of the watercourse, the buffer zone should be measured from the top of the bank (Figure 1b).

Plate 3. Excellent fish habitat. Note well-vegetated streambanks and natural riffle-pool sequence.

Plate 4. Severe encroachment on streambank in light industrial area. Steep banks barren of vegetation provide no cover for stream fishes.

c. Under some circumstances, part of this buffer zone may be utilized as a recreational area by construction of a bicycle or hiking trail within the buffer zone.

d. Linear facilities paralleling a stream should be outside a buffer zone. In such an instance, part of the buffer zone may be used to provide infrequent access for maintenance of facilities. If these facilities require frequent maintenance, an access road should be built outside of the buffer zone.

1.1.2. Poorly Defined Watercourses

Poorly defined bog streams also require protection although many provide only minimal fish habitat. These streams tend to hold back storm water and prevent both downstream flooding and habitat degradation due to bottom scour during storms; in addition, they tend to slowly release water to help maintain sufficient baseflow which provides fish habitat during dry periods.

Guidelines

a. Poorly defined streams which provide critical fish habitat should be protected by a 10 m buffer on either side of the watercourse margin (Figure 1a).

b. The degree of protection required for poorly defined watercourses should be determined early in the planning stage through consultation between the developer or engineer and Fisheries and Oceans.

c. Excepting the above, guidelines from Section 1.1.1 apply.

1.2 Stream Alterations or Improvement

Streams in urban areas are altered for a variety of given reasons ranging from flood control to maximizing land area available for development. The typical channelization or diverted stream in Newfoundland is a flat-bottomed ditch which has virtually no vegetation on its banks and follows the shortest distance between two points (Plate 6). In contrast, natural streams normally meander considerably to produce a much lower gradient with lower water velocities. The substrate of natural streams is highly variable, normally with a series of riffles and pools. Finer substrate materials which accumulate in meanders provide spawning habitat and pools provide cover for larger fish (Plate 3).

Ideally, planners should endeavour to design all developments (both residential and industrial) to leave streams in their natural state (Plate 5), protected by buffer strips as described in Section 1.1. Practically speaking, however, some degree of flood protection is necessary in many Newfoundland developments. The recommended methods are dikes constructed outside the buffer zone (Fig. 2) or a floodwater by-pass (Fig. 3) which would contain or carry excess flows. In the latter case, control devices should be in place which

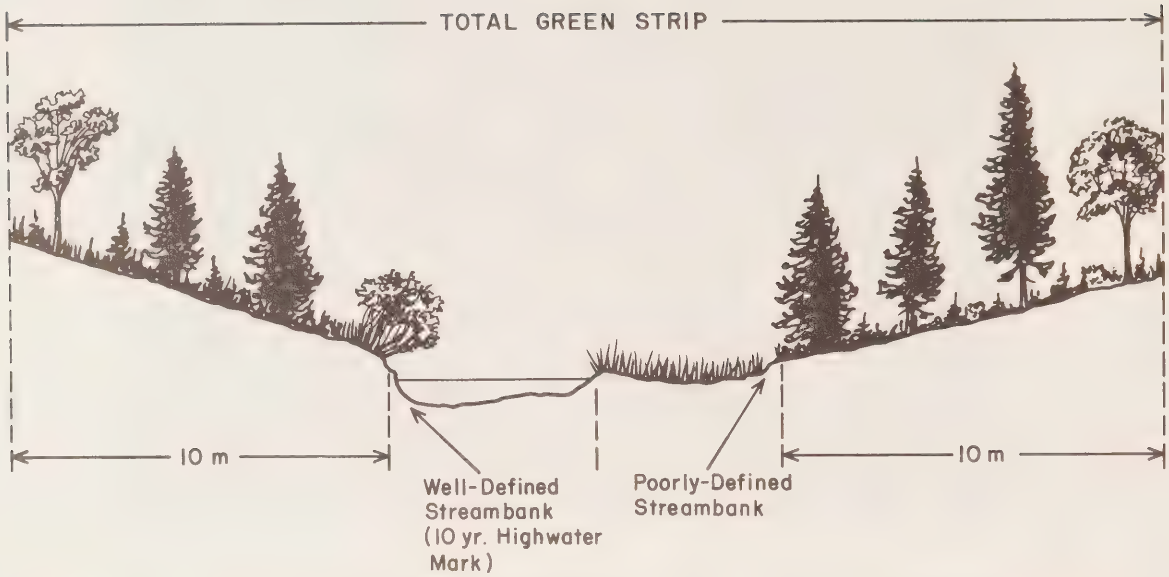


Figure 1a. Example of adequate buffer zones along streams with poorly defined stream banks (adapted from Fisheries and Marine Service 1978).

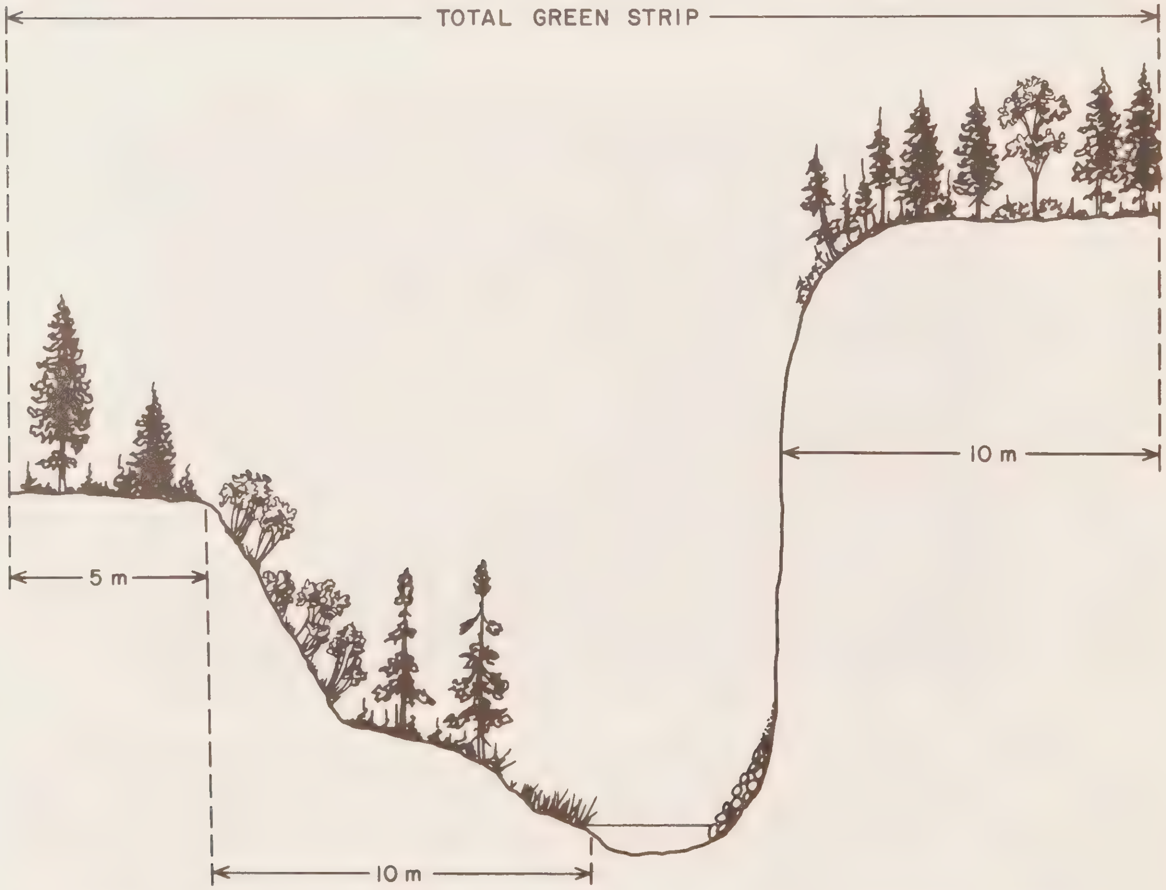


Figure 1b. Example of adequate buffer zones along streams with well-defined stream banks (adapted from Fisheries and Marine Service 1978).

Plate 5. With the exception of the road in the foreground, this stream is well-buffered from surrounding development.

Plate 6. Recently channelized stream provides negligible fish habitat.

a.

b.

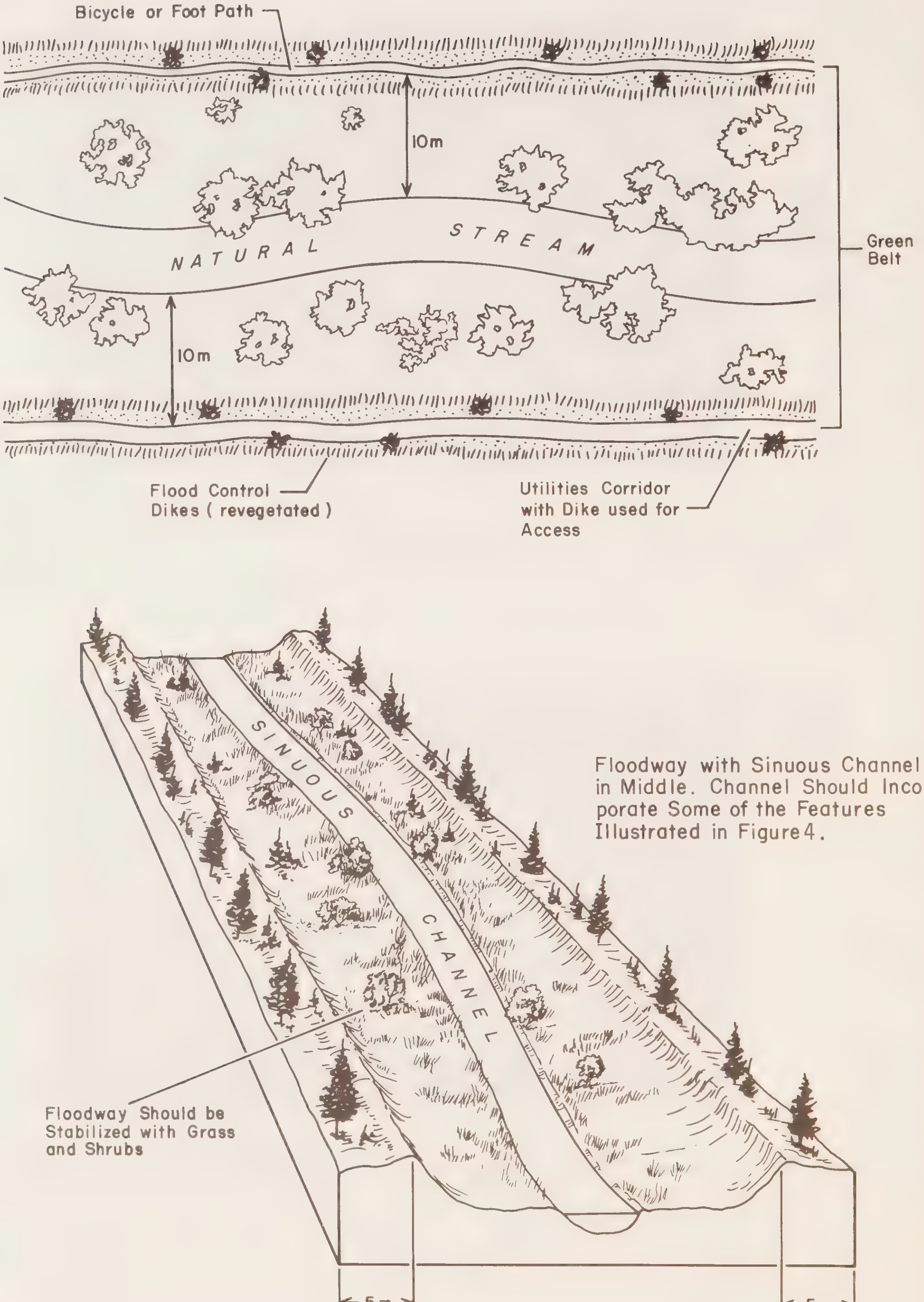


Figure 2. Alternative methods for flood control.

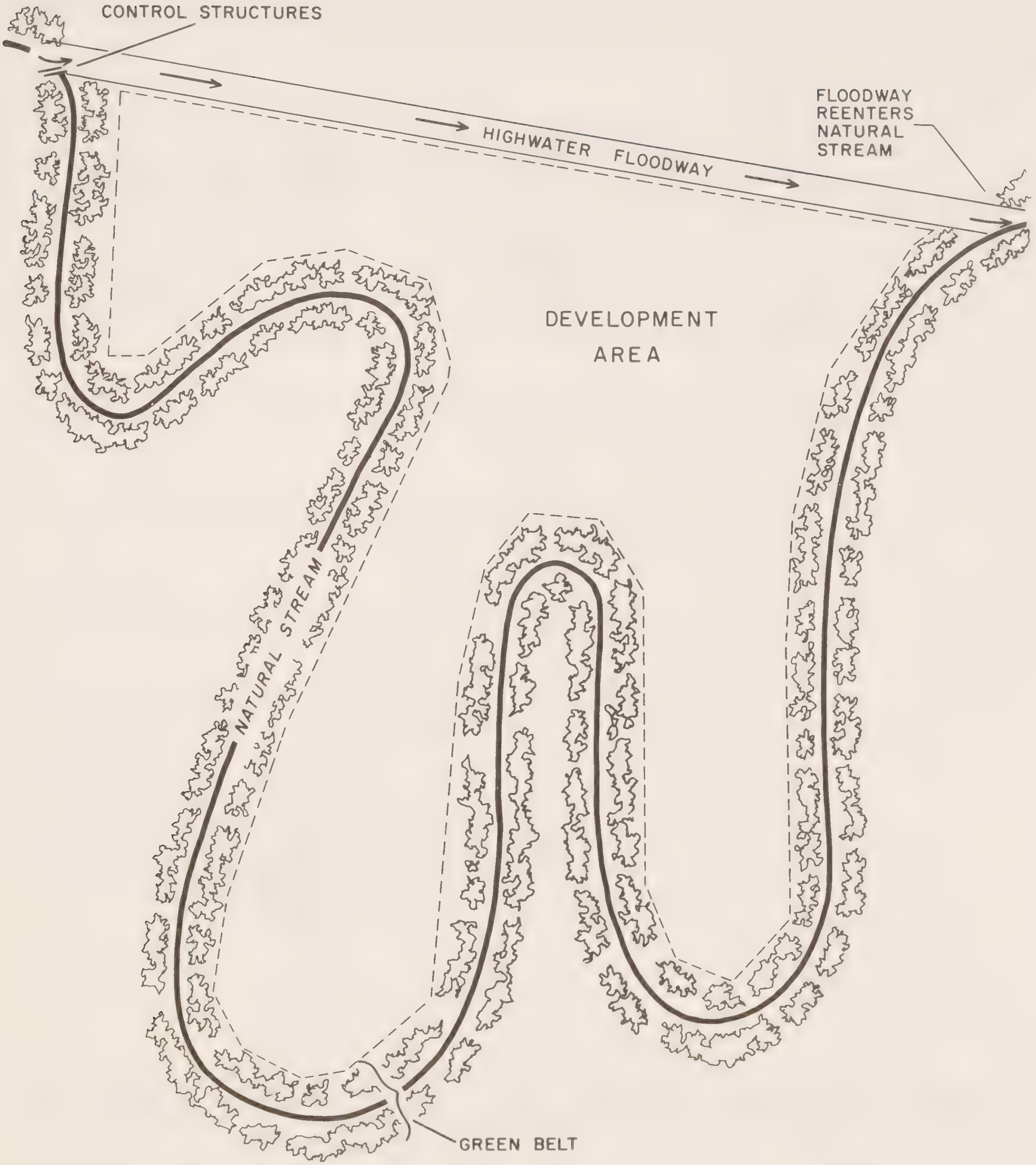


Figure 3. Floodwater by-pass carries peak flows to protect development area but leaves fish habitat intact.

ensure that only flows greater than the mean annual flow are diverted into the by-pass. Both of these methods maintain all existing fish habitat. In some instances when space is at a premium, it may be acceptable to include a landscaped dike which could form the base for a bicycle trail or hiking trail thereby making the stream right of way an even more attractive aspect of the development (Fig. 2a).

1.2.1 Channelization and Stream Diversion

If complete channelizing or diversion is necessary to carry anticipated flood flows, a channel within a channel approach should be used (Fig. 2b).

Guidelines

a. Alternatives to channelization or diversion including diking, construction of a floodwater by-pass and limited stream improvement are preferred.

b. Major rechannelization or diversions should be justified as essential when approval for such works is requested from the Department of Fisheries and Oceans.

c. Any plan for channelization or diversion should incorporate provisions for replacing fish habitat lost in the original channel (Fig. 4 and Appendix 3).

d. A buffer strip of 5 m on either side of the channel (measured from the top of the banks) should be revegetated and protected from further development and vehicular traffic in perpetuity.

e. Channels constructed should not be significantly deeper than the natural watercourse to avoid disruption of the groundwater table.

f. Linear facilities (e.g. transmission lines, roads, pipelines, water and sewer lines) parallelling the channelized stream should be outside the buffer zone but under some circumstances the buffer zone may be utilized as a means of access for infrequent maintenance of these facilities. If facilities require frequent maintenance, an access road should be constructed outside the buffer zone.

2.0 INSTREAM ACTIVITIES

2.1 Dams

Dams are frequently constructed across streams or lake outlets to create larger or deeper waterbodies or to divert streamflow for other purposes. The purpose of dams within the urban context inlcude:

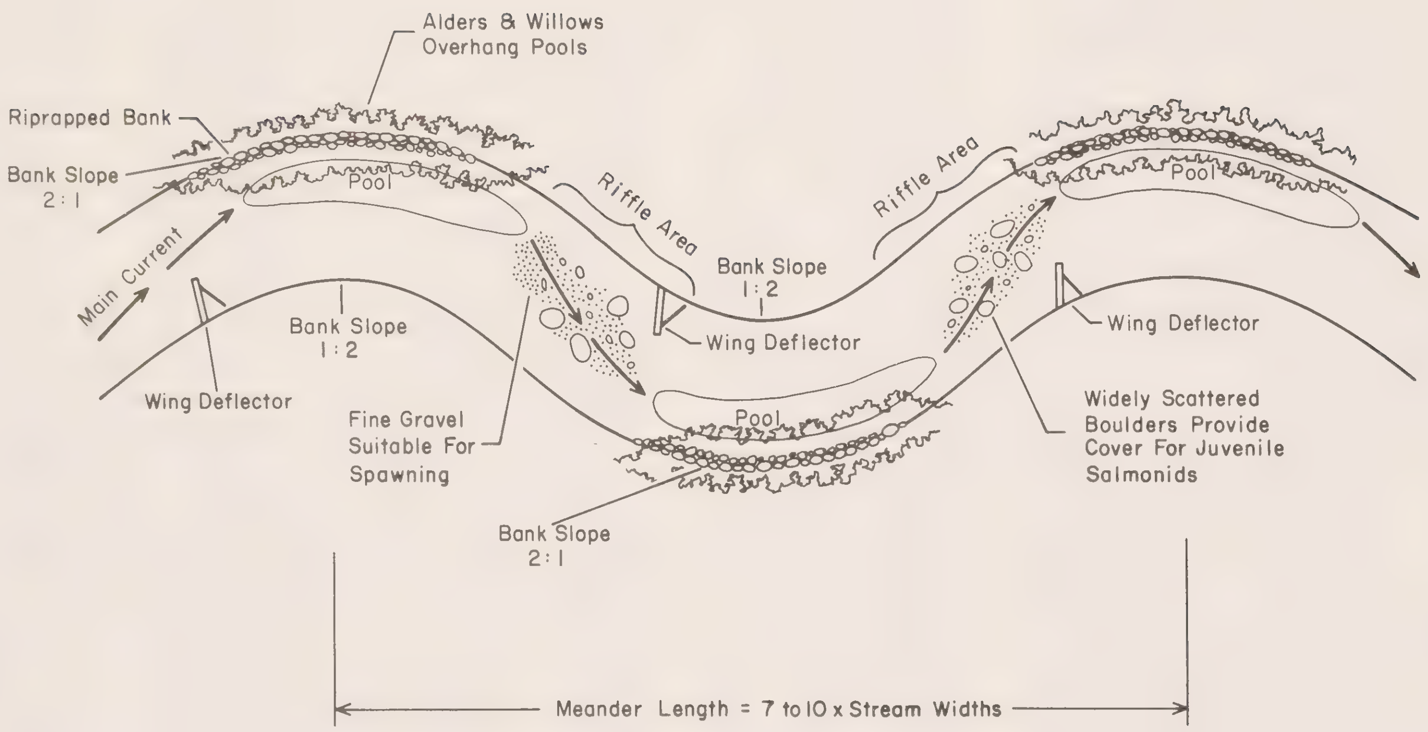


Figure 4. Acceptable habitat improvement for channelized or diverted stream (adapted from Jewell 1981).

1. flood control to protect downstream areas by controlling release from headwater areas,

2. forming or deepening lakes or lagoons in urban parks for recreational purposes, and

3. diverting streamflow for industrial or recreational use.

These dams may affect fish populations by preventing normal migration between feeding, rearing and spawning areas. This type of impact is generally most severe when the dam is situated in the lower reaches of a drainage frequented by anadromous fish (either salmon or sea trout). In this case, a dam without adequate provisions for fish passage will essentially eliminate the sea-run fish stock by blocking their progress upstream or by making them more vulnerable to fishing activities while they wait for flow conditions to improve. In addition the reservior created behind the dam may inundate, and result in the loss of, important spawning or rearing habitat.

Guidelines

a. In all watercourses where fish are present, the location and design of a proposed dam must be approved by the Department of Fisheries and Oceans. In some cases a slight alteration of the damsite will significantly reduce impact.

b. All dams in watercourses utilized by fish should be designed to incorporate a fishway to permit passage of upstream migrating adult fish of the size present in a given watercourse.

   (Many fishway designs are available in the technical literature and will not be discussed in this document. Readers requiring more detail should consult the Technical Bibliography).

c. When water is diverted for out of stream uses, sufficient instream flow should be maintained to preserve fish habitat. The methods of computing the amount of flow required to maintain fish habitat are many and varied. (See Appendix 4.)

2.2 Stream Crossings

Urban development necessitates frequent crossings of watercourses by various means. Roads, sewers, water mains, power lines and telephone cables must cross streams within urban areas and, in most instances, do so more or less at random unless the river is very wide or deep.

General Guidelines

a. All linear facilities should cross a watercourse within specific selected corridors to minimize habitat disruption.

b. Avoid use of heavy equipment within the active stream channel (i.e. use a backhoe from shore rather than a bulldozer in the stream whenever possible).

c. Care must be taken to avoid spillage or dumping of cement, lime or fresh concrete into the stream.

d. Instream work should be scheduled between 1 June and 30 September to avoid siltation of the watercourse during the critical spawning period and when fish eggs are incubating (usually October to May) in most Newfoundland streams.

e. Excavated materials should be placed away from the stream banks so that heavy rains or flooding will not wash it into the stream.

f. If stream width is such that instream work is necessary, the stream should be diverted to allow the work to be done in the dry. (See Section 2.2.2.)

g. Disturbed streambanks should be stabilized as soon as possible to prevent erosion. Prior to seeding, woodchip mulches or commercial anti-erosion mats may be used to prevent erosion.

h. When stream crossing structures are replaced, structures with equal or superior fish passage features should be employed.

2.2.1 Bridges

Bridges are the recommended method for crossing all large and medium-sized watercourses and all watercourses supporting anadromous fishes. They are also recommended whenever the natural stream channel is too steep to accommodate maximum culvert slopes recommended in Section 2.2.2.4.

Guidelines

a. Bridges should be located on straight sections of a stream to minimize possible scour near abutments.

b. Abutments should be above the normal wetted perimeter of the stream to avoid stream restriction.

c. Concrete aprons under bridges are not recommended since they block fish passage at low flows.

2.2.2 Culverts

Culverts are the most commonly used method for road stream crossings and are generally adequate for preservation of the fish resource in small and medium-sized streams provided they are correctly installed. From a fish

habitat standpoint, culverts should always be oversized (i.e. should be able to pass the highest mean monthly stream flow without channel restriction and velocity increase). As a general rule, fish passage during flood flows is not a concern in Newfoundland urban rivers since floods are normally short in duration.

The problem of fish pasage through culverts has been the topic of extensive research, especially dealing with upstream migration of Pacific salmon in western North America. However, with a few notable exceptions the urban areas of Newfoundland have greater impact on local movements of stream resident trout than on migration of large sea-run fish. Therefore, the following guidelines are recommended for urban streams which do not support significant populations of salmon or sea trout. Where searun fish occur, the guidelines presented by Dane (1978a, b) are recommended.

2.2.2.1 Culvert Location

Guidelines

a. Unless detailed biological investigations prove otherwise, assume all streams support viable fish populations and require habitat protection. If in doubt, contact your local fisheries officer.

b. Select culvert site where channel gradient is as close to zero as possible and where there are no sudden increases in water velocity immediately up or downstream.

c. Locate the culvert on a straight stream segment rather than on a bend.

d. Locate the stream crossing in an area where the existing streambanks are stable and well defined.

2.2.2.2 Culvert Type

Bottomless multiplate arch or dome-type culverts are preferred over the standard cylindrical type since they will provide less construction of the streambed and a natural substrate which facilitates fish passage (Fig. 5a).

2.2.2.3 Culvert Capacity

Guidelines

a. Culverts should be overdesigned, i.e. designed to carry more than anticipated maximum flows without completely filling. A designed capacity for 1 m 50 year floats is recommended.
b. If multiple culvert installations are required, only the one which will carry flow at low water need be designed to facilitate fish passage (Figure 5, Plate 7).

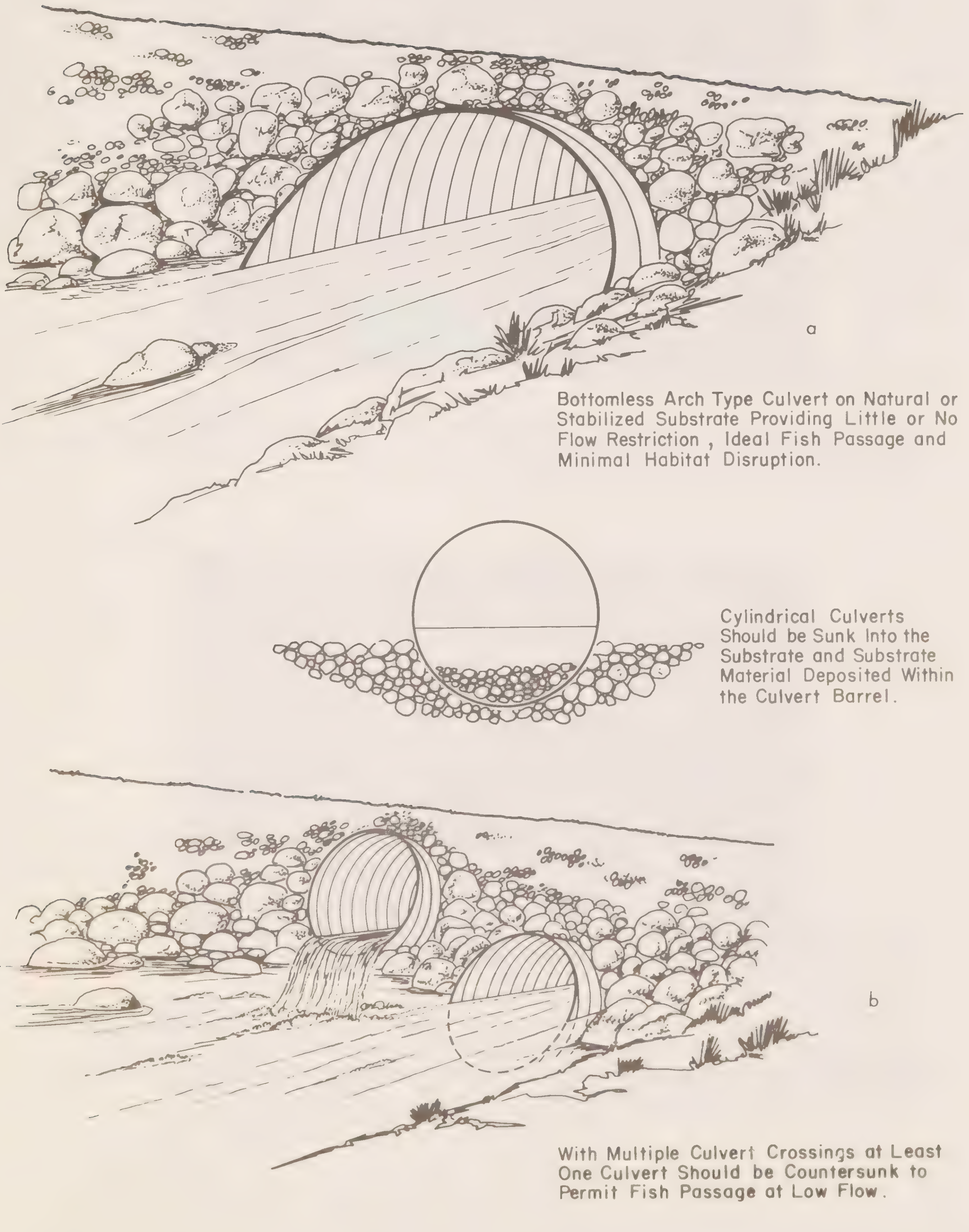


Figure 5. Recommended culvert designs and placements.

Plate 7. This multiple culvert crossing is a barrier to fish passage. One or two large multiplate culverts would both pass stream flow with less chance of obstruction and permit fish passage.

Plate 8. Concrete lip at downstream end of the otherwise excellent arch plate culvert creates a barrier to upstream fish movement. If such lips are necessary, they would incorporate a V-notch to permit fish passage at low flow

c. Culvert capacity should include provision for gravel deposition within the culvert.

2.2.2.4 Culvert Slope

Examination of maximum culvert slopes previously recommended for Newfoundland streams indicated that they are probably restrictive, allowing unobstructed passage for only the larger fish in a stream-resident population. By limiting access to all stream habitat-types to only the larger fish in a population, the full productivity of that population may not be realized. Therefore, modifications have been made to existing slope criteria in order to ensure passage for a greater size range of fish.

Guidelines

a. Maximum slopes recommended for cylindrical culverts having an outside diameter greater than 0.75 m are: 1.0% for culverts less than 25 m in length, and 0.5% for culverts greater than 25 m long. Previously recommended slopes of 5% for culverts 15 m or less in length, 3% for culverts 15-30 m, and 1.5% for culverts 30 m or more should not be incorporated unless a baffle system is employed. The above maximum should not be exceeded even when baffles are in use.

b. For cylindrical culverts with outside diameters less than 0.75 m, the recommended maximum slope is 0.5% regardless of the length of the culvert.

c. The slope should ideally parallel that of the natural streambed to avoid 'jumps' at either end. These dropoffs are detrimental to fish passage and may endanger the crossing itself by eventually undetermining the culvert.

d. As a general rule average water velocities in a culvert should not exceed 1.2 m/s for culverts less than 24 m long, or 0.9 m/s for culverts greater than 24 m long.

2.2.2.5 Culvert Installation

Guidelines

a. If cylindrical culverts are used, they should be installed such that the culvert bottom is below the natural streambed level according to the following criteria: for culverts less than 0.75 m outside diameter, 1/3 the diameter below streambed; and, a minimum of 30 cm below the bottom for culverts greater than 0.75 m diameter. This should permit deposition of stream gravel in the culvert as a result of natural bed migration and provide a natural appearing streambed to enhance fish passage. Proper culvert installation has been shown to provide habitat suitable for fish spawning within a culvert under some conditions (see Kratt 1981).

b. During culvert construction, any streambed improvement necessary should be done with a backhoe working from the bank rather than instream work with a bulldozer. If instream work is necessary it should be done in the dry. (See Section 2.2.4.)

c. Concrete aprons which extend beyond the end of a culvert to prevent undermining should not be used unless properly backflooded by tailwater control structures. These aprons should otherwise stop at the end of the culvert.

d. Culverts should be placed such that a minimum depth of 15 to 20 cm of water is maintained throughout the length during periods of minimum stream discharge.

2.2.2.6 Culvert Baffles and Fishways

Guidelines

a. Fish passage in larger culverts may be facilitated by installation of baffles. A wide variety of baffle types are described in the technical literature. No specific designs are recommended but should be considered on a site specific basis.

b. A baffle system should be placed in all culverts longer than 25 m with a slope of more than 0.5 % and in those culverts less than 25 m long with a slope of more than 1.0%.

c. Fish passage in small culverts is best facilitated by proper installation and sufficient culvert size.

d. Techniques to maintain coarse rubble substrate in culverts of all sizes should be investigated since this is generally preferable for passage of smaller fishes.

2.2.2.7 Tailwater Control

Tailwater control is a preferred method for ensuring adequate water depth within a culvert and reducing water velocity within the culvert barrel. These structures are essential for culverts which have a downstream 'waterfall'. (See Plate 8.) The most practical tailwater control structure is a rock-lined pool construction of riprap or gabions similar to Fig. 6. Similar tailwater control structures may be constructed using wood or concrete. It is essential that these tailwater control structures have a notch in the middle to permit fish passage at low streamflow. If the drop from the control structures is more than 15 cm, a series of 'steps' should be formed to lower the water to the natural streambed level (Fig. 6).

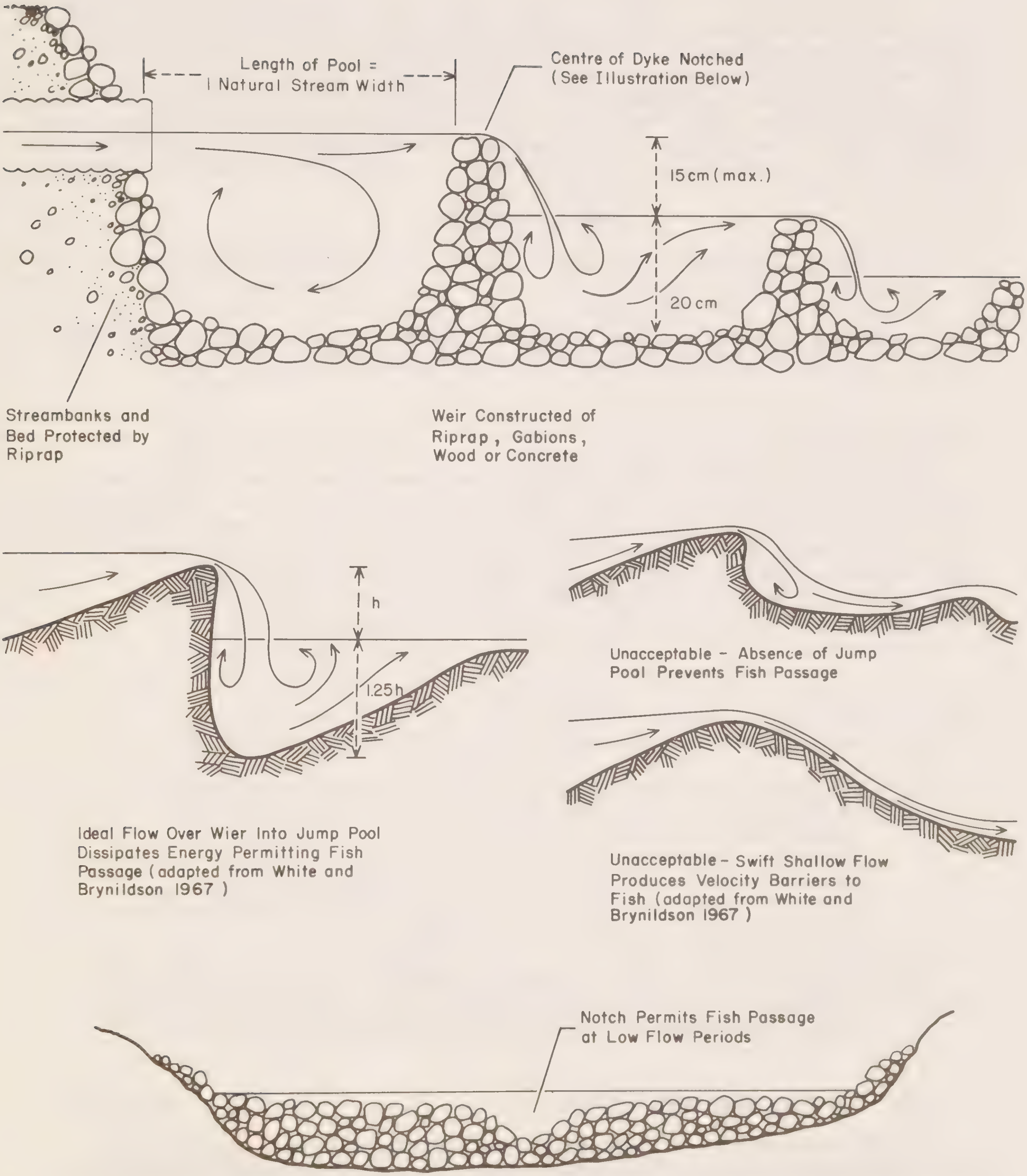


Figure 6. Some features of tailwater control structures. Riprap types used in illustration but other materials are equally effective.

2.2.2.8 Culvert Length

Overall culvert length has been suggested as a possible obstruction to fish movements, independent of streamflow. There are no conclusive data regarding this problem but culverts as long as 800' (240 m) have been successfully navigated by anadromous salmon provided current velocities were sufficiently low and sufficient water depth was maintained. Effects on resident species are unknown. The darkness of long culverts has also been suggested as a possible obstruction but again, no conclusive evidence exists.

Guidelines

a. Culverts should be no longer than is necessary for a road to cross at right angles.

b. Under no circumstances should a long section of stream be permanently enclosed by culverts since this eliminates fish habitat.

2.2.3 Fords

As a general rule, fording should not be considered as an alternative to culverting or bridging within the framework of urban development since it costs little more to install a temporary culvert crossing than to conduct sufficient stream improvement to produce a satisfactory ford. Uncontrolled fording of small feeder streams on construction sites can cause severe siltation of important fish habitat in the receiving waterbody. If a ford must be constructed, the following guidelines should be incorporated.

Guidelines

a. Fording should be avoided in potential spawning areas.

b. The entire ford area should be stabilized with coarse material ($\geq$12.7 cm diameter) unless it is natural bedrock.

c. Sufficient stream improvement should be conducted such that the ford neither obstructs streamflow nor forms a waterfall which could obstruct fish passage. A minimum water depth of 46 cm should be maintained across the ford at all times.

d. Fords should be situated where streambanks are stable and where approaches to the crossing have low slopes. If slopes are steep or unstable they should be stabilized to prevent erosion.

2.2.4 Underground Installations

In urban areas streams must be crossed by water pipes, sanitary sewers, underground cables, etc. Ideally the number of crossings should be minimized.

Necessary crossings should follow roads, thereby reducing overall impact on the stream. Construction of underground facilities will, of necessity, cause massive disturbance to the streambed and may produce severe downstream siltation. If this siltation is short-term and if it occurs when fish are not spawning, it is likely that normal fluviatile processes will soon remove deposited silt and minimize long-term impact. However, during urban construction many stream crossings are frequently required and their cumulative effect will likely yield severe habitat degradation (at least in the short-term).

Guidelines

a. In order to minimize habitat degradation, the stream should be diverted through a temporary channel during the actual stream crossing. This temporary channel should be constructed from the downstream end and lined with coarse material or polyethylene prior to the excavation of the upstream end and diversion of the stream. (Figure 7).

b. Once the stream channel has been crossed and the crossing site has been stabilized with coarse material, the temporary channel should be blocked off and streamflow re-routed to the original streambed.

c. In the case of small streams, construction of temporary dewatering channel may be replaced by construction of a coffer dam to stop streamflow at the construction site and maintaining downstream flow by means of an elevated culvert (Fig. 8) or pumps. These techniques should be utilized only for short-term crossings since they block fish movements. Pumps should be started prior to blockage of the stream to prevent de-watering of downstream habitat.

d. Construction and removal of blockage or diversion dams should be by backhoe from shore, rather than by instream activity with heavy equipment.

e. Exact procedures should be determined on a site-specific basis on consultation with the Department of Fisheries and Oceans.

3.0 STORM SEWERS

The usual practice in Newfoundland is to empty storm sewers directly into the nearest stream without any treatment or storage (Plate 10). This inflow of storm sewer water greatly changes the basin hydrology both in the rate of runoff and the water quality.

3.1 Quantity of Runoff

Water enters the storm sewer system primarily as a direct runoff from large immpervious surfaces such as parking lots, roads, and building

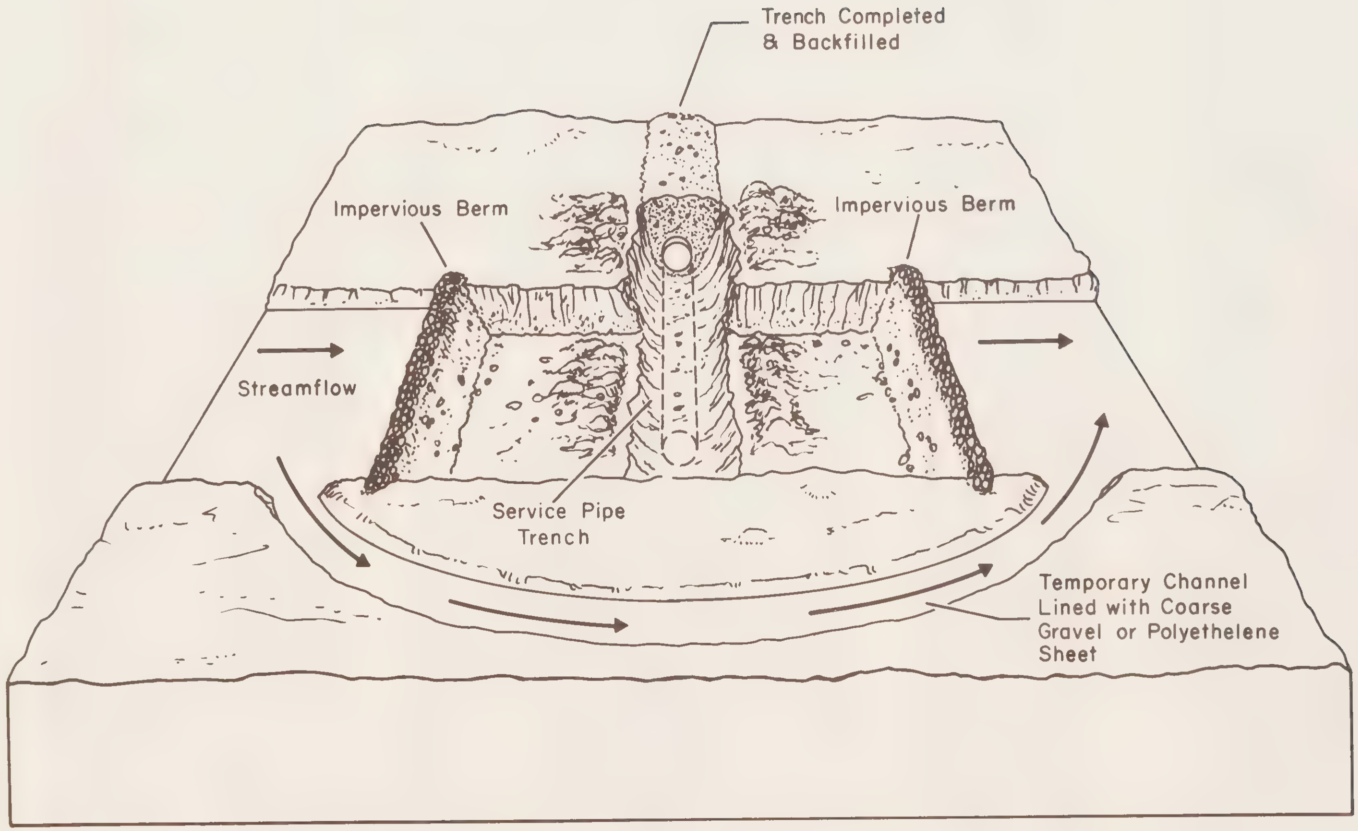


Figure 7. Streamflow diverted around construction area by use of a temporary channel.

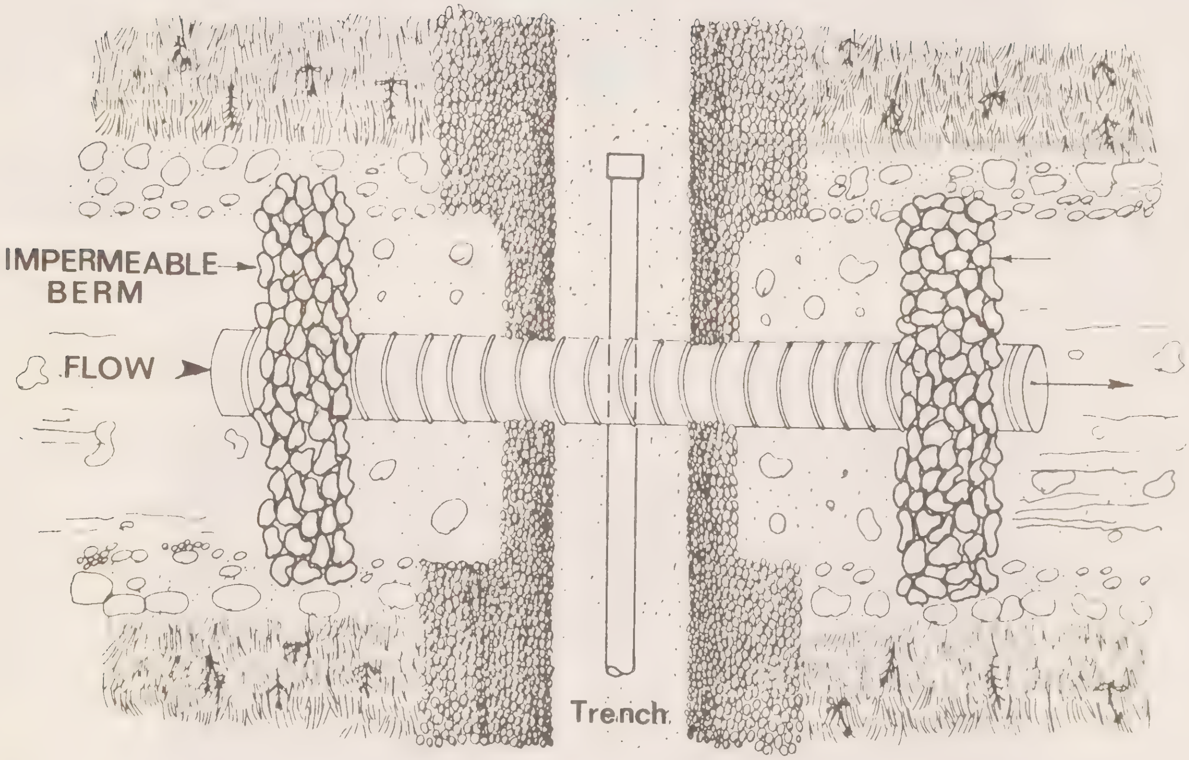


Figure 8. Stream crossing dewatered by means of an elevated culvert (from Fisheries and Marine Service 1978).

Plate 9. Small streams on construction sites should be diverted or culverted to prevent siltation of fish habitat downstream when it is not feasible to leave them in their natural state.

Plate 10. Storm sewer discharge into otherwise excellent fish habitat. Some riprap added at the outflow would dissipate the energy of storm water and minimize local channel degradation.

roofs. This form of runoff is almost instantaneous and behaves in a similar manner to precipitation that falls directly into the watercourse and its tributaries. As a watershed becomes increasingly urbanized, the problem will magnify and result in severe flooding especially in the lower reaches of the watercourse. Water also enters the storm sewer system as a result of percolation through the soil and inflow. This latter type of storm sewer discharge more closely resembles natural throughflow and results in comparatively less impact on the basin hydrological response.

Rapid runoff during storms and reduced baseflow conditions which result from reduced infiltration have adverse effects on fish habitat. Extremely high flow rates during and subsequent to storms may cause bank destabilization and erosion which may persist at lower streamflows. These spates may also displace spawning gravels which are stable at lower stream velocities. Reduced baseflow conditions between storms decreases the amount of useable fish habitat and may cause reduction in the potential standing stock of fish in a watercourse.

Modern technology has produced several alternatives whereby these impacts may be mitigated. The first and preferred method would be a complete separation of storm sewer systems from streams frequented by fish. However, it is understood that given the terrain and financial constraints present in most developments in the province, this is not practical. A brief discussion of several methods used for the management of storm water is included in Appendix 6.

Guidelines

a. Storm water management should be required as part of all new industrial or residential projects which will render more than 25% of the total surface of the development area impervious to water.

b. Storm water control may be instituted either as part of the development or as part of the overall storm water system.

c. The management system should be designed to retain sufficient runoff such that the response of a watershed to rainfall resembles its natural state.

d. Several acceptable means of storm water detention are

   i. soakage pits or perforated pipes (Figure 9),

   ii. super pipes (Figure 10),

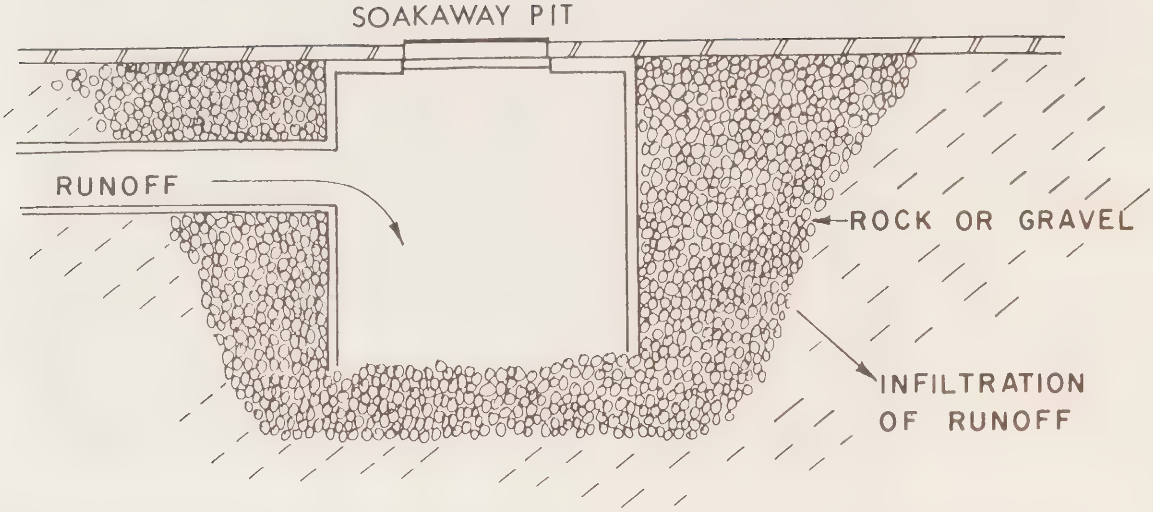
   iii. surface detention ponds or swales (Figure 10),

   iv. underground holding tanks (Figure 11),

   v. Storm water should enter a watercourse as close to the mouth of the stream as is technically feasible.

e. Storm water should enter a watercourse as close to the mouth of the stream as is technically feasible.

a.



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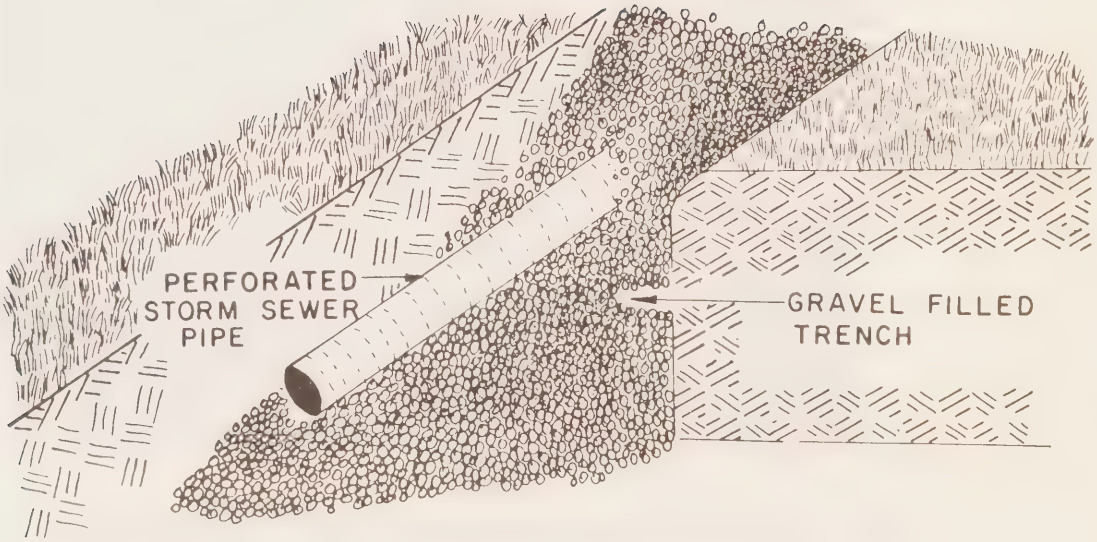

Figure 9. Soakage pit and perforated pipe provide means of storm water disposal which have minimal impact on fish habitat and stream flow (from Fisheries and Marine Service 1978).

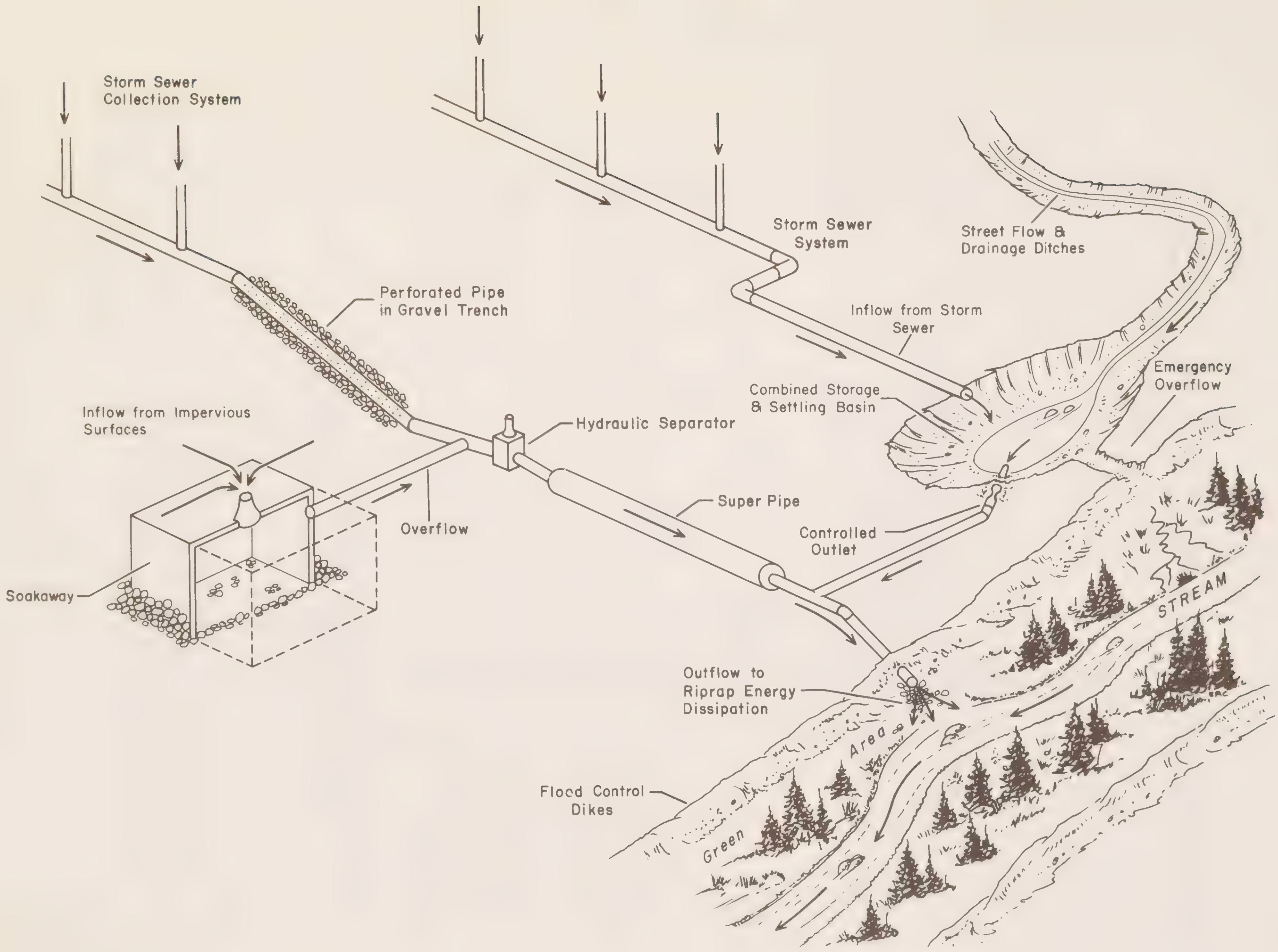

Figure 10. Some alternate means of storm water management.

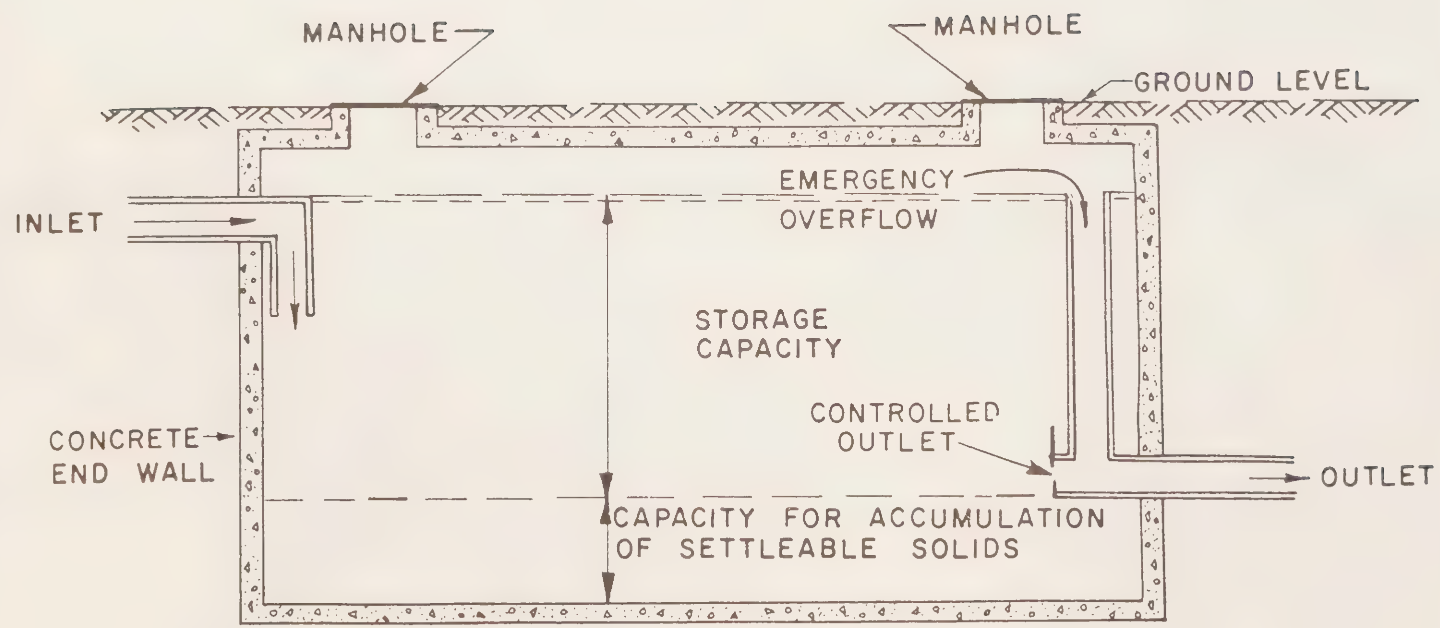

Figure 11. An underground holding tank and settling facility (from Fisheries and Marine Services 1978).

f. Storm sewers should discharge preferably into a vegetated buffer zone or onto riprap energy dissipators rather than directly into the stream.

3.2 Quality of Runoff

3.2.1 Point Source Pollutants

Urban runoff can contain a wide variety of contaminants including bacteria, heavy metals, road salt, sediment and a wide variety of organic compounds including petroleum hydrocarbons. Some of these deleterious substances enter the storm sewer system and subsequently the streams through connections (accidental or otherwise) between the sanitary and storm sewer systems. Others enter the holding tanks for various substances in industrial area are emptied, accidentally or otherwise, into the storm sewer system rather than the sanitary system. The remainder are flushed into the storm sewer by runoff water.

Guidelines

a. Care should be taken to avoid any inter-connections of sanitary and storm sewers.

b. All industries using water for any purpose whereby it may become contaminated (e.g. washing industrial equipment or motor vehicles) should not discharge contaminated water into storm sewers or streams without proper treatment. If treatment facilities are not feasible the water should be held in tanks for disposal in sanitary landfill.

c. Storm runoff from industrial areas which is likely to contain any deleterious substances should be directed into the sanitary sewer system, a treatment facility or holding tanks for later disposal in sanitary landfill. It should be noted that most of the erodable or soluble materials will be removed by the first part of the storm, hence holding facilities or treatment facilities need not be designed for maximum annual storms.

d. All water entering a storm sewer system which is later discharged directly into a watercourse should conform to appropriate provincial regulations and be free of substances deleterious to fish.

3.2.2. Non-Point Source Pollutants

Water quality problems arising from general urban runoff are not usually as severe as the afore-mentioned areas but several studies have revealed considerable increases in a wide variety of pollutants as a result of non-point source urban runoff. Most of these pollutants are in association with suspended solid particles, hence treatment to remove suspended solids will solve most of the problem.

Guidelines

a. Individuals intending to discharge storm water into watercourses frequented by fish should be aware of provincial statutes which regulate water quality (e.g. Water and Sewage Regulations, Schedule B).

b. Some 'polishing' of storm water may be affected by discharging the storm water into a bog area where sediment particles and associated pollutants will be removed by the peat and vegetation.

c. More severe water quality problems may be solved by installing settling basins (Fig. 12) or mechanical or hydraulic separators between the storm sewer outflow and a watercourse.

d. Storm water treatment facilities need not be designed for yearly maximum storms since, unless severe erosion occurs, most pollutants are carried into the first flush of water at the beginning of a storm.

e. The degree of treatment required may be dependent upon the sensitivity of fish habitat in the receiving waters.

4.0 SMALL STREAMS

One method commonly used to classify streams within a watershed is the systematic ordering of the stream branches. Each non-branching headwater segment of the watershed is designated a first order stream, streams which receive only first order segments are termed second order, and so on.

Climatic and topographical conditions in most of Newfoundland produce an abundance of small, first and second order streams, many of which are poorly defined. However, their importance to trout production should not be underestimated. An ample supply of ponds and bog-lands which tend to stabilize the flow in small streams and the lack of other species which would compete with salmon and trout for habitat and food have resulted in many small streams, especially second order streams, being the most productive salmon and trout habitat in Newfoundland (pers. comm. R. J. Gibson, DFO, St. John's). Not only are small streams sometimes more productive than larger Newfoundland rivers, but they contribute flow in all cases to these larger third and fourth order rivers which makes the water and habitat quality far downstream vulnerable to impacts upon the smaller headwater streams. Thus, the protection of small streams is just as important, and in some cases even more critical, than the protection of larger rivers.

Guidelines

a. Prior to development, all permanent watercourses, either well- or poorly defined, should be located and assessed as to their suitability for fish haibtat. (Contact Fisheries and Oceans for assessment.)

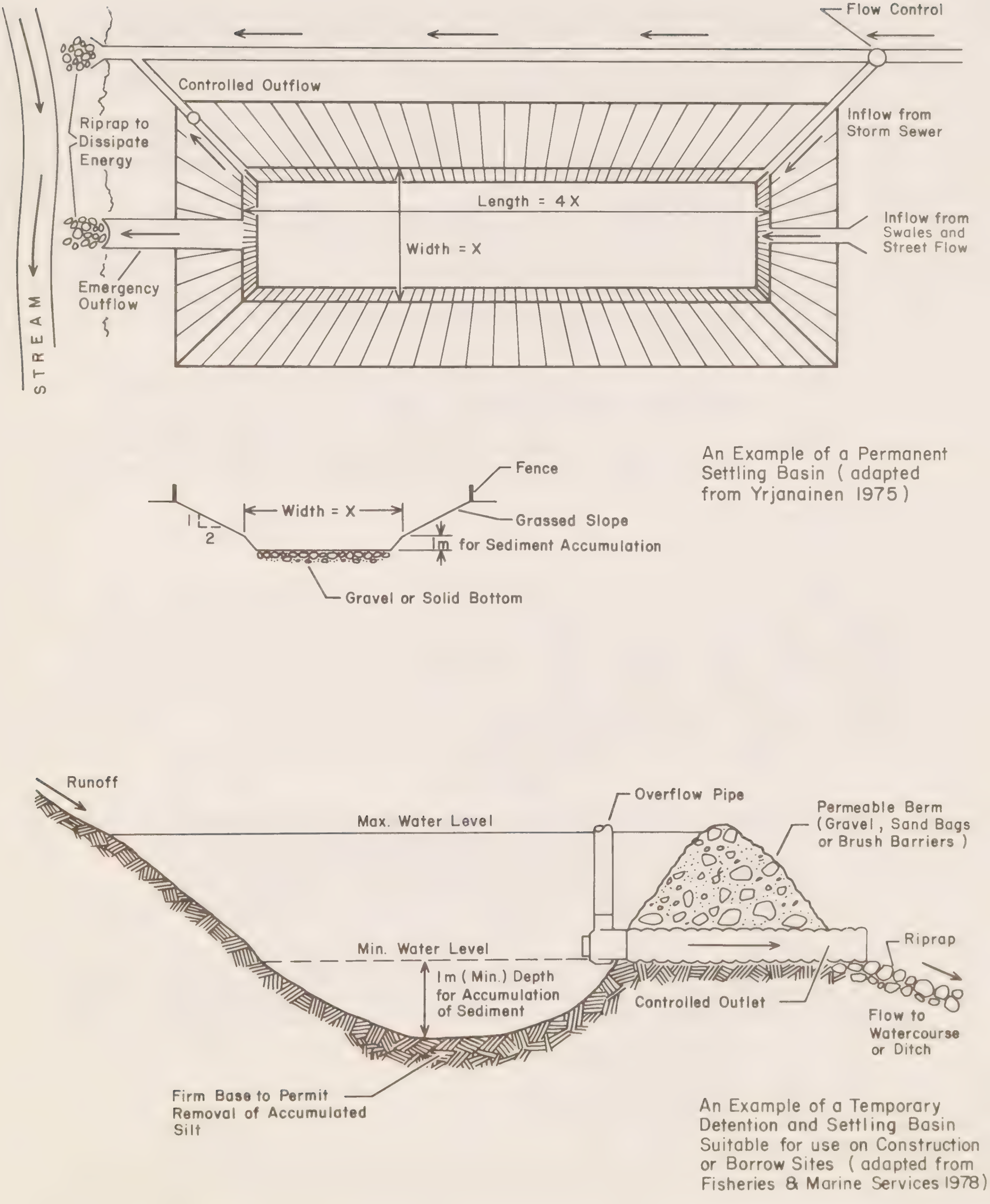

Figure 12. Permanent and temporary settling basins to reduce suspended sediments.

b. Streams within a development area which constitute important fish habitat should be afforded protection as described in Section 1.1.

c. Smaller or intermittent streams which afford no fish habitat should receive the following protection:

   i. If possible, the stream should be re-routed around the construction area or at least channelized to prevent random migration of the stream during site preparation.

   ii. Unlimited fording by construction equipment should not be permitted (Plate 9). Culvert crossings are preferred with well-stabilized fords as a secondary option.

   iii. A sediment trap should be constructed downstream of the construction site. (Fig. 12)

   iv. Banks of the channel should be stabilized and revegetated subsequent to completion of the job.

   v. Incorporation of a natural watercourse as part of the enclosed storm sewer system is not recommended and should be viewed only as a last resort.

5.0 BORROW SITES

Removal of gravel or other materials from streams, stream banks, or beaches used by capelin for spawning is an obvious source of impact on fish through direct destruction of habitat and is expressly prohibited under the Fisheries Act. Less obvious, but potentially of considerable impact on fish habitat, are gravel removal sites on hillsides or near small feeder streams. Runoff from these areas can contribute substantial quantities of sediment to a watercourse and impair habitat quality.

Guidelines

a. Further to restriction of gravel removal from streambeds, no gravel or other borrow materials should be removed from streambanks or within the buffer zone as specified in Section 1.1.

b. Small feeder streams as defined in Section 4.0 should be diverted around borrow sites to avoid siltation.

c. Runoff control devices or sediment traps should be placed downslope of hillside gravel removal areas to prevent sedimentation or nearby watercourses. Sediment traps suggested for this use (Fig. 12) are:

   i. permeable gravel dikes
   ii. gabion walls
   iii. sand bag dikes, and
   iv. brush barriers

d. Contractors are cautioned that provincial regulations forbid a discharge of water containing more than 30 parts per million suspended solids into any watercourse.

6.0 GENERAL CONSTRUCTION PRACTICE

6.1 Site Preparation

A considerable amount of the stream siltation attributable to urban development occurs during the actual construction phase of the development. Much of this impact could be reduced or eliminated by preliminary reconnaissance to develop an erosion control program. Proper site preparation procedures could then greatly decrease the sedimentation and virtually eliminate costly construction stoppages and remedial actions.

Guidelines

a. Early in planning stages conduct a joint engineering and environmental reconnaissance of the site to locate and identify potential fish habitat and small feeder streams or temporary watercourses which will require special treatment.

b. Streams which afford fish habitat should be treated as described in Section 1.1.

c. Small streams and temporary watercourses should be treated as described in Section 4.0

d. Necessary erosion control measures such as interception ditches, and small stream diversions should be completed prior to clearing of work site (Fig. 13).

e. Do not clear work site and remove top soil prior to commencement of construction and limit cleared and graded are to minimize area of bare soil.

f. Install sediment traps at the downslope end of the construction sites. (Refer to Appendix 6 and Technical Bibliography for descriptions of a wide range of these devices.) These traps should be inspected and given necessary maintenance subsequent to any significant rainfall.

g. If construction schedule will result in extensive areas which will be denuded of vegetative cover for an extended period, anti-erosion devices such as woodchip or gravel mulches or commercial anti-erosion mats or sandbag check dikes should be considered for more susceptible areas.

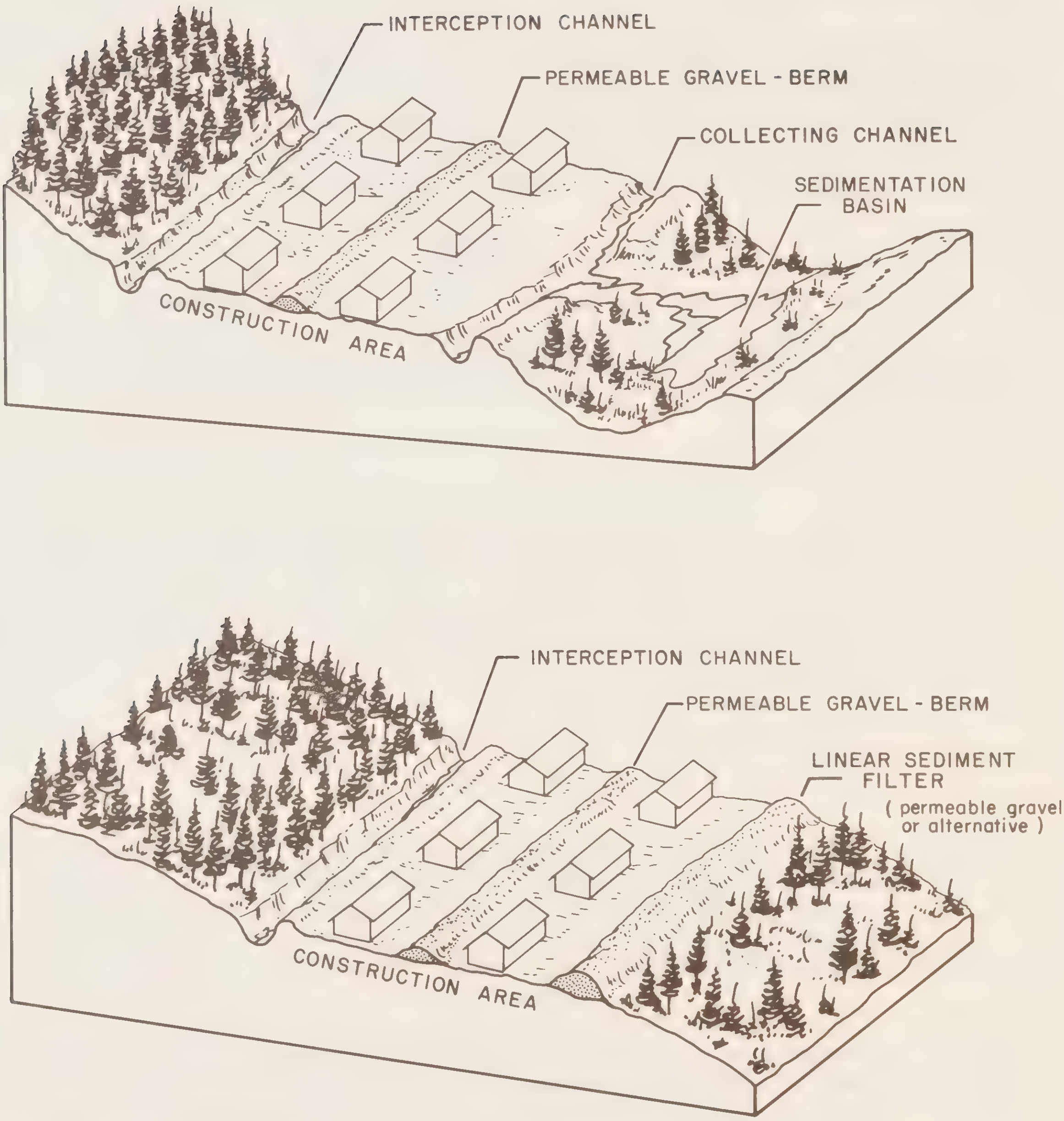

Figure 13. Some methods to control erosion on construction sites.

6.2. Site Reclamation

Subsequent to the completion of construction, the site should be reclaimed immediately to limit sustained erosion.

Guidelines

a. All slopes of the construction site should be reduced as much as possible. If long slopes are present, they should be benched to interrupt the flow of water and minimize erosion.

b. Vegetative growth should be restored on all denuded areas by seeding or laying sod. Prompt re-establishment of vegetation will likely reduce the need for costly remedial measures caused by erosion damage to slopes. For this reason hydro-seeding may prove to be cost-effective in spite of a relatively high initial cost.

c. Once all construction activity is completed and vegetation has been re-established, sediment traps and any accumulated sediment should be removed.

6.3. Toxic Material Storage

Accidental spills or fuels, lubricants or other chemicals which enter a stream either directly or through the storm sewer system may eliminate fish from otherwise good habitat. Proper storage and handling of these materials would preclude these accidents.

Guidelines

a. Any toxic or potentially toxic liquid including fuels, lubricants, acids or alkalis should be stored in a designated area, surrounded by an impervious berm which would contain a spill of all the stored liquid.

b. Solid toxic materials including cement, lime and sulphur should not be stored within 25 m of a watercourse or flood channel.

c. Any spillage of toxic substances into any watercourse or waterbody should be reported immediately to your local fisheries officer.

6.4 Waste Disposal

Guidelines

a. Waste lubricants should not be allowed to enter streams or storm sewers, i.e. maintenance personnel on construction sites should be provided with proper receptacles for waste oil when performing routine maintenance.

b. Machinery maintenance should not be performed in or near a stream, ditch or storm sewer. Some specific examples are washing out cement mixers, changing oil, greasing, spray painting, cleaning of spraying equipment, etc.

c. Construction wastes (wood, paint cans, etc.) should be transported to nearest dump or deposited in suitable receptacles rather than the nearest stream or ditch. Proper control of waste during construction will avoid the necessity of sending a 'clean-up crew' later.

d. Waste receptacles should not be located adjacent to streams, ditches or storm sewers.

ACKNOWLEDGEMENTS

Many individuals contributed toward the preparation of these guidelines. We especially acknowledge the co-operation of the following: A. Cheeseman -- City of St. John's Engineering; W. Earle -- Earle and associates Ltd.; L. Felt -- SAEN, F. Hann -- CBCL Ltd.; R. Pottle -- Newfoundland Department of Highways; and W. Yoxall -- Memorial University of Newfoundland. Original illustrations were prepared by S. Crowley and of Lundrigan-Crowley, Drafting and Creative Design Ltd. and H. R. Mullett of DFO. R. A. Buchanan and J. Richardson of LGL Limited provided valuable editorial advice. Special thanks to R. J. Gibson, R. F. Goosney, and R. N. McCubbin of DFO for the critical reviews of the manuscript and constructive advice. The various manuscripts were typed by J. Brenton, B. Hogan, J. Y. Lannon, K. M. Lynch and K. A. Scott.

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APPENDIX 1

Depicted herein are the application and authorization forms for works or undertakings which may affect fish and fish habitat. These forms are available from the following DFO Offices in Newfoundland and Labrador (see Fig. 14 for District and Regional Boundaries).

DFO, Newfoundland Region

<u>District 1</u>

Area Manager
Department of Fisheries and Oceans
P.O. Box 5667
St. John's, Newfoundland
A1C 5X1

Phone: 772-5046

<u>District 2</u>

Area Manager
Department of Fisheries and Oceans
P.O. Box 760
Marystown, Newfoundland
AOE 2MO

Phone: 279-2675

<u>District 3</u>

Area Manager
Department of Fisheries and Oceans
P.O. Box 557
Grand Falls, Newfoundland
A2A 2J9

Phone: 489-5601

<u>District 4</u>

District Protection Officer
Department of Fisheries and Oceans
P.O. Box 3002
Goose Bay, Labrador
AOP 1CO

Phone: 896-3263

DFO, Gulf Region

Area Director
Department of Fisheries and Oceans
Herald Towers, 6th Floow
Herald Avenue
Corner Brook, Newfoundland
A2H 4B4

Phone: 634-7962

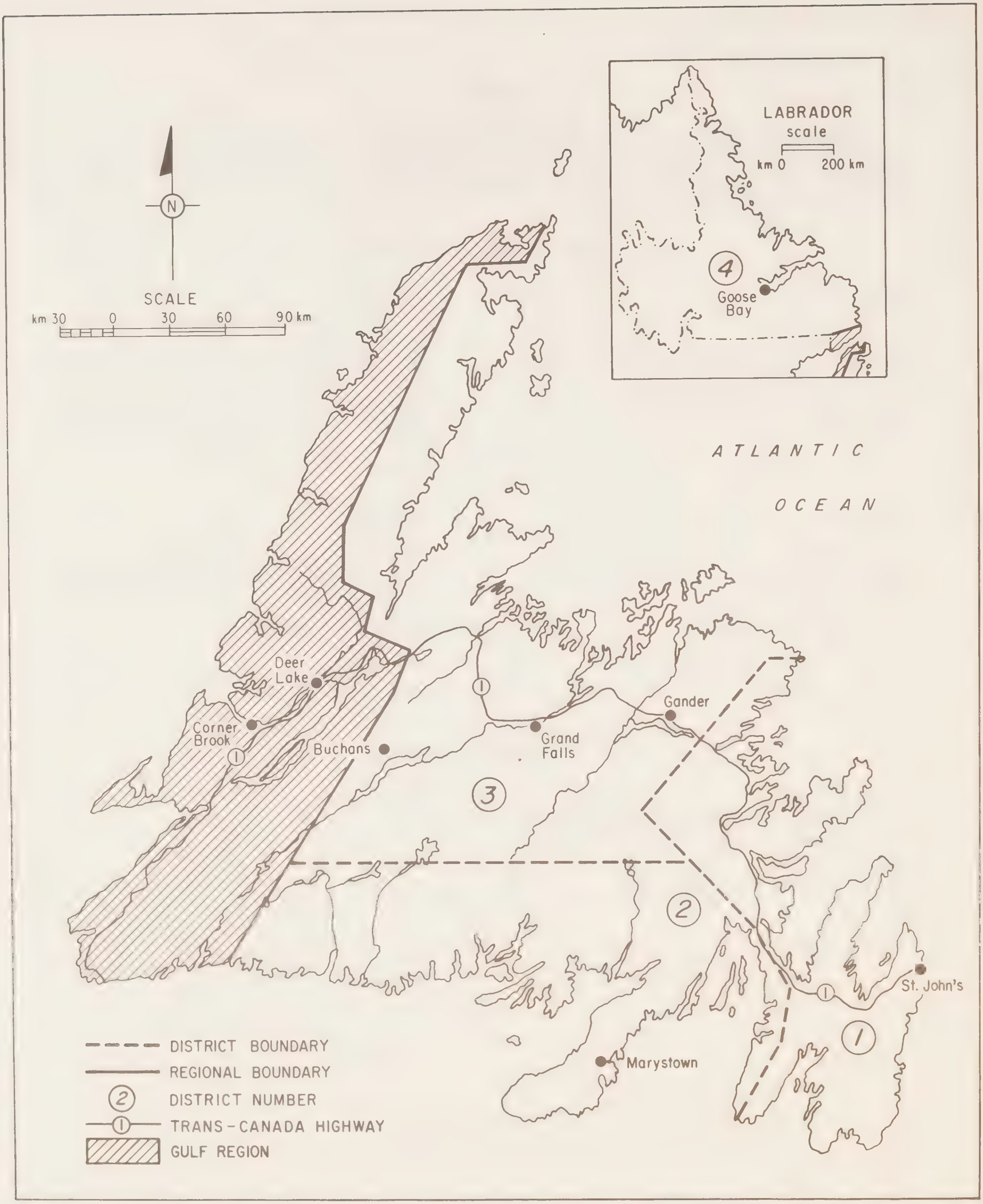

Figure 14. Boundaries of DFO management areas - Newfoundland Region

APPLICATION FOR AUTHORIZATION FOR WORKS OR UNDERTAKINGS AFFECTING FISH HABITAT

Location of Proposed Project

Application No.
(For Office Use Only)

Name of Watercourse: ______

This Watercourse is a Tributary of: ______

Nearest Community: ______

Distance from Nearest Community: ______

Type of Activity

General Data:

_____ Construction _____ Repair _____ Upgrading _____ Modification

_____ Removal _____ Other (Specify) ______

Specific Data:

_____ Bridge
_____ Culvert
_____ Dam
_____ Stream diversion
_____ Stream realignment
_____ Channelization
_____ Wharf - Breakwater
_____ Dewatering
_____ Gravel removal
_____ Obstruction removal - bypass
_____ Stream utilization - recreation
_____ Erosion control
_____ Flood protection
_____ Stream traverse
_____ Other

Plans, Procedures and Specifications Including Materials and Chemicals to be Used

(Use attached sheet if necessary; attach documents to application)

______

Reason for Proposed Activity

______

Type of Equipment to be Used Instream (If Any)

______

Schedule

Proposed Starting Date: _____ Day _____ Month _____ Year

Proposed Completion Date: _____ Day _____ Month _____ Year

Approximate Timing of Instream Work: _____ Same as above, or

From _____ Day _____ Month _____ Year to _____ Day _____ Month _____ Year

NOTE: All plans, procedures, specifications, analyses and other information relating to the work or undertaking must be included or attached. Also studies, analyses, evaluations, samples and other information relating to the water, place or fish habitat affected by the work or undertaking must be attached (if applicable).

TO APPLICANT: Retain Green Copy, Return All Other Copies to District Office.

DISTRIBUTION: District Office - White; Applicant - Green; Regional Office - Blue; Field Office - Yellow.

DETAILS SHEET

Application NO. ___________
(For Office Use Only)

Please provide details of proposed activity including map of its location.

TO APPLICANT: Retain Green Copy, Return All Other Copies to District Office.

DISTRIBUTION: District Office - White; Applicant - Green; Regional Office - Blue; Field Office - Yellow.

I, ______________________________, the undersigned hereby request authorization to carry out the works or undertakings described on this application form. I understand that the approval of this application, if granted, is from a Federal Department of Fisheries and Oceans standpoint only and does not release me from my obligation to obtain permission from other concerned regulatory agencies.

Should this application be approved, I hereby agree to carry out all activities relating to the project within the conditions set out by the Department of Fisheries and Oceans and within the designated time frame.

Applicant's Signature ______________________________

Applicant's Name (Please Print) ____________________

Applicant's Address ________________________________

____

Applicant's Telephone Number _______________________

Date ____

I have submitted this application on behalf of:

☐ Myself

☐ Agent Representing the Undersigned.

Name of Person, Company, or Department ______________________________

NOTE: Major projects (i.e. bridges, culverts, dams, stream realignments, etc.) will require one or more of the following additional information packages. If applicable, please check the appropriate additional information you have enclosed.

_______ Engineering Scale Drawings

_______ Scale Drawings

_______ Dimensioned Drawings

_______ Engineering Specifications

_______ Other

DISTRIBUTION: District Office - White; Applicant - Green; Regional Office - Blue; Field Office - Yellow.

GOVERNMENT OF CANADA

FISHERIES AND OCEANS

Application No. ______________

Authorization No. ______________

AUTHORIZATION FOR WORKS OR UNDERTAKINGS AFFECTING FISH HABITAT

Authorization Issued To:

Location of Project:

Valid Authorization Period: From: ____ Day ____ Month ____ Year To: ____ Day ____ Month ____ Year

Description of Works or Undertakings:

COPY

Conditions of Authorization:

VOID

The holder of this authorization may undertake only those works or undertakings described above. All conditions set out by the Department of Fisheries and Oceans must be adhered to.

The authorization form must be held on site and work crews should be made familiar with conditions noted above.

This authorization is from a Federal Fisheries standpoint only and does not release the holder from its obligation to obtain appropriate approvals from other concerned Federal, Provincial or Municipal Agencies.

Date of Issuance: ______________

Approved By: ______________

DISTRIBUTION: Applicant - White; District Office - Green; Regional Office - Blue; Field Office - Yellow.

APPENDIX 2

Greenbelts along watercourses both preserve fish populations (Gunderson 1968; Burns 1970; McMynn 1970) and prevent damage due to flooding (Parrett 1973; Walsh 1973). Streambank vegetation in the form of overhanging shrubs (usually alder and willow), deadfall, or roots of undercut trees and shrubs provide important escape cover for stream-resident fishes. Several published studies record significantly greater standing stocks of trout in stream reaches with overhanging vegetation than in reaches where vegetation has been removed (Boussu 1954; Gunderson 1968; Boreman 1974). The streamside vegetation also provides an important food source for stream-resident fishes, both directly through terrestrial insects which fall into the stream from over-hanging bushes and indirectly by supplying food to aquatic invertebrates in the form of leaves and twigs which fall into the stream. Trees, bush and grasses on the streambanks stabilize the soil along the shore, inhibiting erosion during high discharge periods. The vegetation also acts as a filter to runoff water, both slowing its rate and removing some of the suspended sediment. Shade from streamside vegetation has been demonstrated to have an important moderating effect on stream temperature (Greene 1950; Burns 1970; McMynn 1970).

The width of green areas recommended in various jursidictions is variable as dictated by local conditions. For example, in North Carolina the recommended buffer zone is 5 stream widths up to a maximum of 15 m on each side (Wingate et al. 1979); in residential areas of British Columbia a buffer zone of 18 m from the stream centreline or 15 m from the high water mark, whichever is greater, is recommended whereas a 30 m buffer is recommended for industrial areas (Fisheries and Marine Service 1978). Whipple et al. (1981), while assessing the erosional potential of watercourses, considered a buffer zone of greater than 50 feet (15 m) to be excellent and less than 10 feet (3 m) to be poor. Only natural wooded strips were included as buffer zones; landscaped lawns or gardens were not considered to be equivalent. A clear correlation was illustrated between the presence of an adequate buffer zone and the degree of bank erosion; however, the difference between the degree of protection afforded by excellent (>15 m) and moderate (3 to 15 m) buffer zones was indistinct.

Recommended buffer widths in most jurisdictions are somewhat subjective based more on the judgement and experience of local professionals than on hard scientific data. In preparing the guidelines for Newfoundland, we have also utilized an intuitive approach based in part on the 5 stream width guideline of Wingate et al. (1979) to a maximum width of 10 m on each side of stream. The smaller buffer zones recommended in these guidelines are acceptable due to the lower erodability of soils in most of urban Newfoundland and the characteristics of local vegetation and landform.

Many poorly defined watercourses, such as those through bogs and fens, are often critical to the hydrological regime and fish habitat quality of Newfoundland streams. In most Newfoundland watersheds, the soil layer is very thin covering either bedrock or compacted glacial till which have low permeability to infiltrating water. As a result, runoff after rainfall is rapid and is followed by a severe reduction in streamflow which can greatly restrict the amount of available fish habitat. The organic deposits which form the bogs and fens act as giant sponges during precipitation, holding large amounts of water

and then slowly releasing it to the watercourse during the succeeding days. This dampening effect stabilizes flow regimes thus enhancing fish habitat downstream. The organic soil and vegetation of the bog areas also removes silt and pollutants from runoff water which could otherwise adversely affect fish. The margins of the bog area should also be protected from encroachment to ensure that the bog vegetation itself is not destroyed.

APPENDIX 3

Habitat Improvement in Channelized or Diverted Streams

Channelization or diversion invariably results in degradation of fish habitat. The detrimental effects were summarized by Barton and Winter (1973):

1. loss of instream cover for fishes,
2. disruption of the riffle-pool sequence,
3. increased stream velocities,
4. increased erosion and sedimentation,
5. loss of stream-side vegetation,
6. loss in stream length, and
7. loss in aesthetic value of the area.

If the channelized stream reach is a straight ditch with a trapezoidal cross-section and a constant slope, it will provide little or no useable fish habitat.

Optimal trout habitat has been very simply defined by Raleigh and Duff (1979) as clear cold water with a rocky substrate, a 1:1 pool-riffle ratio, some areas of slow deep water, a relatively stable flow regime, well-vegetated stream banks and abundant instream cover. It has been amply demonstrated that the distribution and abundance of fish in a stream is governed by the habitat type and quality (Gunderson 1968; Lewis 1969). Various habitat types are essential for the different life-history stages of a fish population and for general maintenance of habitat quality. Turbulence in riffle areas oxygenates the water and lowers the water temperature. Substrate particle size is usually larger and more diverse in riffles than in pools (Swales and O'Hara 1980). In pools, the increased depth provides shelter for fish and the low current velocity minimizes energy expenditure required to hold a position. However, pool areas generally produce less fish food per unit area than do riffle areas, so excessive pool creation may not be advantageous.

In most situations a natural stream will recover relatively quickly from most types of impact as a result of natural fluvial forces and regrowth of bank vegetation. Channelized streams are, however, very slow to recover to the point where they provide good trout habitat (White 1974). When habitat enhancement has been conducted on channelized whatersheds, significant improvements have been noted in fish standing stocks (Barton and Winger 1973; Lund 1976).

A wide variety of stream habitat improvement devices are described in the technical literature, at least some of which are appropriate for almost all situations which may be encountered as a result of stream channelization or diversion. Hydrological scientists have made great progress in understanding

the physical processes which maintain the various types of stream habitat (Leopold 1968; Keller 1975; Keller and Hoffman 1976, 1977; Keller 1978, Nunnally 1978). Recently fishery biologists have expended considerable efforts in developing various techniques to quantify habitat quality (Hunt 1976; Stalnaker and Annette 1976; Binns and Eiserman 1979; Raleigh and Duff 1979). This greater understanding of hydraulic processes and fish habitat requirements makes it possible to select specific techniques which will greatly improve fish habitat quality (White and Brynildson 1967; Swales and O'Hara 1980; Swales 1982). A reasonable knowledge of both the physical characteristics of the watershed and the nature of the fish population is essential to select the appropriate techniques, since the identical techniques may have different degrees of success in different areas. Warner and Porter (1960) report on attempts at restoring fish habitat in a bulldozed stream in Maine using wing reflectors, rock dams, and spring holes. The wing deflectors and spring holes yielded a high rate of success whereas the rock dams were generally unsuccessful. However, Gard (1961) reports good success using small dams to create fish habitat.

In general, the ideal techniques for providing fish habitat in a channelized watercourse emulate conditions in a natural stream.

Channel Morphology

Natural watercourses almost never follow a straight line but are more or less sinuous. This so-called sinuosity has the effect of decreasing the effective gradient of the stream and providing much more fish habitat of much higher quality than would an artificially straightened channel. The sinuous channel typically consists of a series of regularly spaced deep areas (pools) and shallows (riffles). It has been demonstrated that a channel constructed to simulate a natural stream is inherently more hydrologically stable than is the more traditional straight ditch (Keller 1975, 1978).

As a general rule, the meander length (see Fig. 4) should be approximately seven to ten times the stream width (Leopold 1968) although this may vary with local terrain. The ideal slope should approximate that of the original stream channel. Pool areas should be located on the bends where they will be maintained by scour at high flow and riffles (rapids) should be located on straight sections of the stream. The inter-pool distance should approximate six stream widths (Keller 1975). Some fine gravels should be situated at the head of riffle sections to provide suitable spawning habitat for resident trout since this is both a preferred ocation for trout to spawn and the gravel is less likely to be scoured during high flow.

The cross-sectional area, width and overall depth of the channel should be as similar to the natural stream as possible. When a large flood channel is required, a small channel within a channel should be constructed (see Fig. 2). For a more detailed discussion of construction techniques and channel designs, the following papers in the Technical Bibliography are recommended: Keller 1975, 1978; Nunnally 1978; Nunnally and Keller 1979; Jewell 1981.

Stream Banks

The banks of channelized stream sections should be constructed with a gentle slope (1:2) to facilitate vegetation growth which will shelter the stream. This slope should be steeper, up to 2:1, on the outside bend of meanders and stabilized with riprap or an acceptable alternative to prevent severe erosion during high flow. These steeper riprap banks on the outside of bends further emulate conditions in a natural stream and will also act to prevent bank erosion.

In order to provide cover for fish, bank vegetation should be encouraged, especially beside pool areas. The recommended shrubs for most Newfoundland streams are willow and alder. These species typically grow down to the waterline and overhang the stream to provide important cover for juvenile and adult fish. Other plants may be used along the riffle areas if so desired, but there should be some vegetation growing along the entire channel. One fairly cost-effective possibility would be to hydro-seed all banks and supplement this with willow and alder cuttings on the meanders. Buffer zones should be maintained around channelized stream sections as well as around undisturbed streams. Buffer width criteria proposed for natural streams should be applied (see Section 1.1). Trees and shrubs planted within the buffer zone will both improve the aesthetic appearance of the channelized area and aid in reestablishing more natural fish habitat.

Instream Habitat Improvement Structures

Instream habitat improvement structures work best in conjunction with a meandering channel and well-vegetated banks. Their positive effect in a straight ditch would be greatly decreased but the final result would be preferable to that of no remedial action. The technical literature dealing with this topic is voluminous and will not be summarized here. These devices generally create fish habitat by modifying streamflow patterns to create pools and deep runs or provide cover directly (Fig. 15):

1. single wing deflectors,
2. bank cover devices,
3. low barrier dams (no more than 30 cm),
4. loosely piled riprap to protect erodable banks,
5. temporary brush shelters (to provide cover until streambank vegetation has been re-established, and
6. boulder groupings.

Other devices which are not generally recommended for use in most Newfoundland streams are digger logs, V or A deflectors and concrete retaining walls.

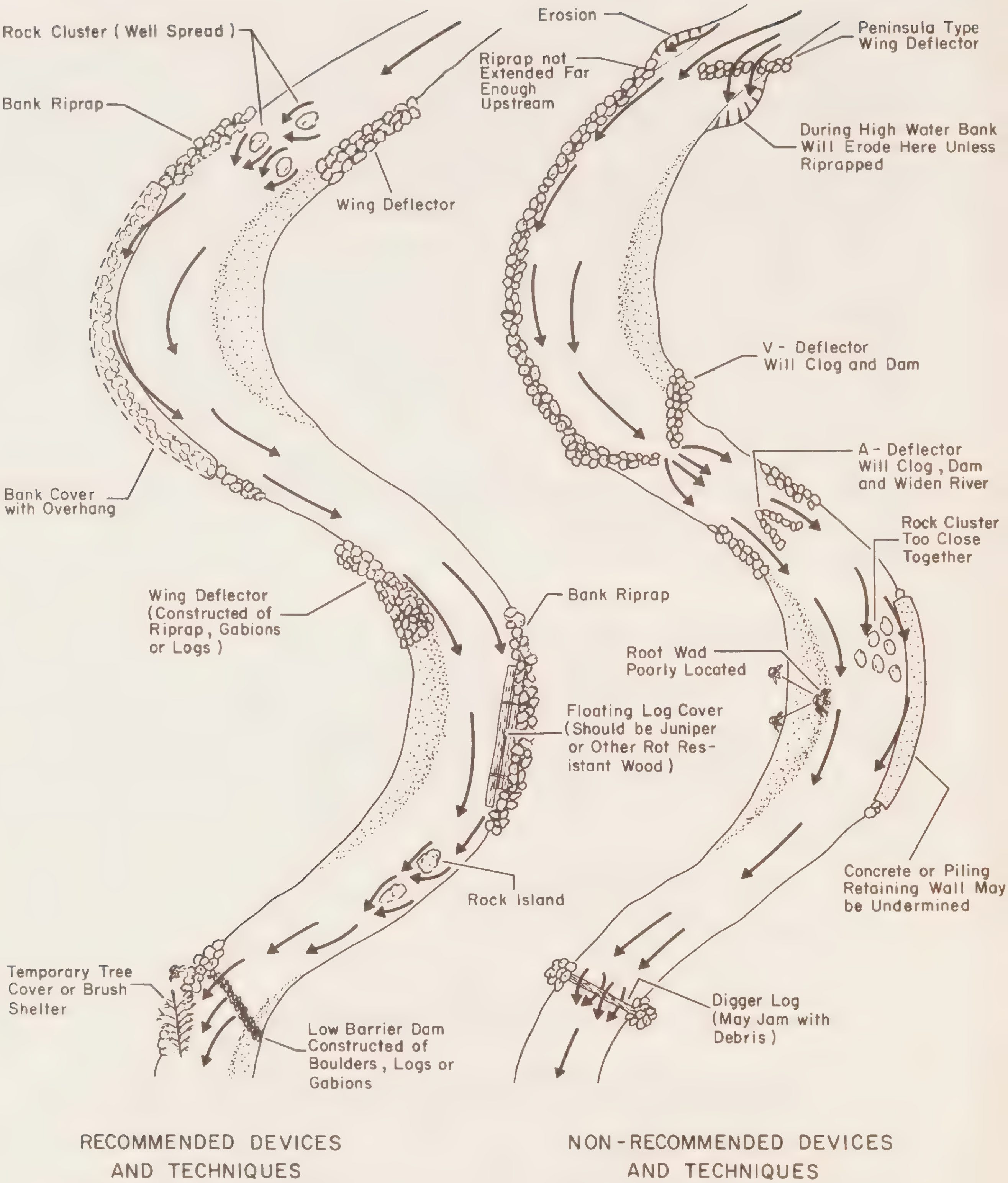

Figure 15. Instream habitat improvement structures.

Readers requiring greater technical details should consult the excellent reviews by White and Brynildson (1967), Fisheries and Oceans et al. (1980), Swales and O'Hara (1980) and Swales (1982).

APPENDIX 4

Instream Flow

Whenever the natural hydrological regime of a watercourse is altered, either by damming the stream or by removing water for out-of-stream uses, sufficient flow should be retained to preserve fish habitat. The problem of instream flow requirements has been examined in some detail by Orsborn and Allman (1976) and Stalnaker and Arnette (1976).

A simple method which is widely used by fisheries workers is the 'Montana Method' as described by Tennant (1976). It is likely that the provisions of this technique are sufficiently conservative to provide reasonable habitat protection in all parts of Newfoundland. The only input required is the mean annual flow (MAF) of the stream, a datum easily extrapolated from the size of the watershed in question and the size of the nearest comparable, guaged watercourse. Briefly, the 'Montana Method' recommends that 60% of the MAF during the summer months (May to October in Newfoundland) and 40% of the MAF during the winter (November to April) be maintained for the protection of fish habitat.

Bins and Eiserman (1979) give further detail pertaining to the quantification of trout habitat as a means to determine instream flow requirements. A more complex computer model has been developed by the Colorado Group to mathematically describe both fish habitat and the anticipated effects of streamflow fluctuations (Milhous and Grenney 1981). This latter model requires detailed measurements taken over the period of a year; therefore is only practical for major developments.

APPENDIX 5

Culverts

Culverts are the standard method for crossing small and medium-sized streams in urban areas. When adequately-sized culverts are installed correctly they cause minimal habitat disruption. Unfortunately the record for either adequate culverts or correct installations has been very poor.

In an undisturbed stream, friction and turbulence induced by boulder and cobble substrates result in much lower velocity near the streambed than that which occurs at mid-water. Moreover, water tends to descend in a series of short steps (riffles) interspersed with pools which dissipate the kinetic energy accumulated in steep sections.

In natural watercourses, stream-resident fish, especially the smaller individuals, rarely have to contend with the high surface velocities apparent in many Newfoundland streams; they normally remain near the bottom in the slower currents. Even small trout are capable of short bursts of considerable speed, (approximately equal to 10 body lengths per second). Small trout are able to move upstream against high velocities by swimming in short spurts and then resting in slow water areas among the substrate. However, larger trout are less able to take advantage of the small low current areas near the bottom because of their size relative to areas of lower velocity. However, this disadvantage is overcome by the ability of larger trout to swim against higher velocities. The ability of trout to make headway against current is affected by water temperature and the size and condition of the individual fish. Since experimental data for most local trout are lacking, approximate maximum sustainable velocities (Table 2) have been extrapolated from rainbow trout (pers. comm. J. Kiceniuk, DFO, St. John's) and Arctic char (Jones et al. 1974).

Table 2. The maximum velocity against which trout can move 100 m in 10 minutes (after Jones et al. 1974).

Fork Lengths (cm)	Velocity (cm/s)
10	36 to 36
20	48 to 60
30	65 to 78

Fish can swim through culverts 50 m and 25 m long in the same time period at velocities 8 cm/s and 12 cm/s respectively higher than the above (Jones et al. 1974). It is likely that Atlantic salmon could tolerate slightly higher velocities.

A culvert represents a drastic change from natural stream habitat. Flow is frequently restricted with a resultant increase in water velocity. In addition, the roughness co-efficient of culverts is lower than in natural streams (Table 3); therefore, less of a 'slow flow' zone along the bottom is produced.

Table 3. Roughness factors for various types of channels (Lauman 1976)

Bottom Type	Roughness Factor
Concrete pipe (smooth)	0.012
Concrete apron (smooth)	0.012
Steel pipe (smooth)	0.012
Corrugated pipe	0.024
Gravel bar (fine gravel)	0.025
Natural bottom (boulders)	0.035 to 0.06

The combination of higher mean cross-sectional velocity plus the absence of rest areas renders many culverts impassable to fish. In order to facilitate fish passage the slope of the culvert should be minimized to reduce water velocities and, whevere possible, a boulder-cobble streambed should be duplicated within the culvert. In instances of high flow rates a system of baffles may be necessary to anchor this substrate.

The following stream crossing types are recommended in decreasing order of preference (adapted from Lauman (1976)):

1. Bridges are the preferred type as they permit retention of the natural streambed and seldom cause fish passage problems.

2. The multiplate arch is desirable for fish passage since it maintains a natural stream bottom. The most frequently encountered problem is an inadequate foundation.

3. Open-bottomed or countersunk concrete box culverts maintain a natural stream bottom and generally are a desirable fish passage structure. Box culverts designed with a bottom should always be countersunk. It may be necessary to construct low crosswalls (baffles) to hold natural bottom materials in a countersunk box.

4. Corrugated pipe generally provides adequate fish passage when placed on a grade less than 0.5 percent. When using this type of installation, the bottom of the culvert should be placed according to the guidelienes listed in Section 2.2.2.5. On steeper grades low crosswalls may be necessary to hold natural substrate materials and facilitate fish passage.

5. Smooth pipe, due to a lower roughness factor, has more problems meeting fish passage criteria than do corrugated pipes. Otherwise, comments for corrugated pipe apply.

6. Any culvert which cannot meet fish passage guidelines when installed normally should incorporate a suitable system of baffles, tailwater water control, or an alternative fishway.

Fish passage problems can be significantly reduced by carefull crossing selection (Metsker 1970). Ideally stream crossings should be situated where:

1. There are no sudden increases in water velocity at the site or immediately upstream or downstream.

2. The channel gradient is as near zero as possible.

3. The stream is relatively straight.

Any time all of the above conditions cannot be met, some fish passage problems may be anticipated.

When the water velocity within the culvert cannot be controlled by culvert type and location, some modifications in culvert design may be necessary to facilitate fish passage. The two most practical methods are tailwater control or a system of baffles within the culvert. The former method involves the construction of a series of small dams or weirs across the watercourse downstream of the culvert. These dams create back pressure within the culvert, both decreasing stream velocity and maintaining water depth. In most cases a series of dams will be required at intervals of approximately one stream width to bring the water level down to that of the natural streambed in a series of steps (maximum height 15 cm) interspersed with rest pools (see Fig. 6). These small dams may be constructed of a variety of materials as dictated by cost and local physical constraints. The most aesthetically pleasing material for urban areas would involve use of riprap or log and piling structures but under some circumstances concrete or gabions may be more practical. Tailwater control is a highly effective and relatively inexpensive method to ensure acceptable fish passage.

Installations of baffles within the culvert barrel are a more costly but equally effective means of ensuring fish passage. Metsker (1970), Lauman (1976), and Dane (1978a, b) discuss the effectiveness of various baffle patterns. One of the most effective types is an offset arrangement consisting of 'paired' baffles attached to the sides and bottoms of the culvert and extending out into the flow of water. One of these is positioned perpendicular to the flow of water and the opposing baffle extends out at a 30° angle to the flow. Both end somewhat short of the midpoint of the culvert (Fig. 16). Baffles may be constructed of wood or concrete at the discretion of the designer. Concrete does have distinct advantages since when it is poured in place it makes a good seal with the bottom of the culvert and conforms to the shape of the culvert. If wooden baffles are used they should be treated to maximize their effective life span.

Persons requiring more detailed information should consult the review of culvert problems and guidelines for culvert design presented by Dane (1978a, b).

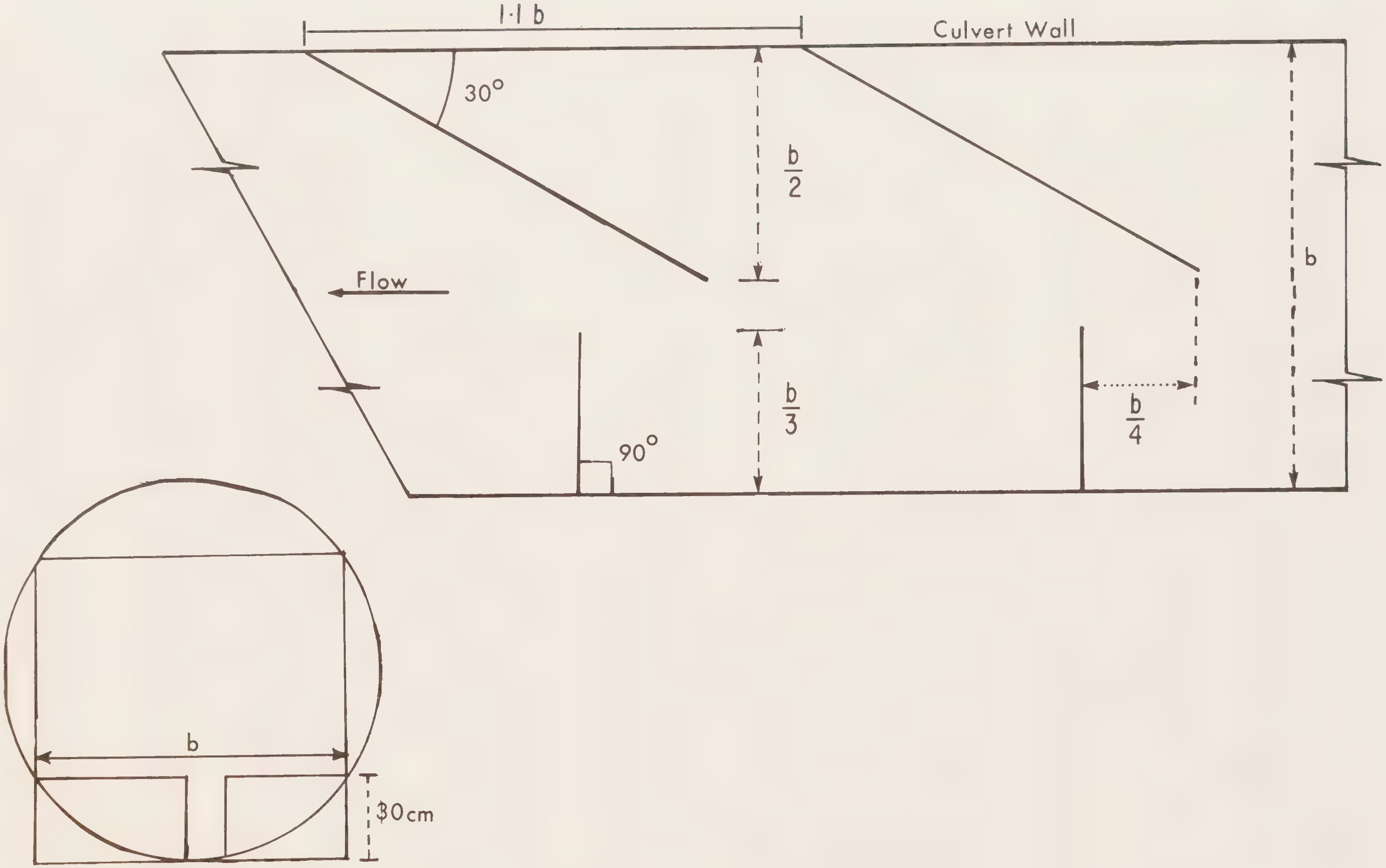

Figure 16. Recommended baffle pattern for cylindrical and box culverts.

APPENDIX 6

Storm Water Management

The concept of storm water management is relatively new in Newfoundland but has been the subject of considerable effort in many other jurisdictions. The management of storm water is usually directed at water quantity or water quality or both. For practical reasons both problems may be treated simultaneously in many circumstances, but for simplicity they will be discussed separately.

Water Quantity

The urbanization of a naturally forested watershed reduces infiltration into the soil, increases overland flow, reduces soil moisture storage and evapo-transpiration, and increases runoff and peak flow (Lull and Sopper 1969). These changes ultimately affect the morphological characteristics of stream channel (Leopold 1968) which in turn affects habitat quality (Lewis 1979; Gorman and Karr 1968; Klein 1979). Changes in stream quality begin to appear when as little as 12% of the watershed has been rendered impervious to water but the problem is not severe until infiltration has been blocked on 30% of the watershed (Klein 1979). Taylor and Roth (1979) monitored changes in the hydrological response of a study basin over a five-year period during which time 25% of the basin was modified by suburban construction. They reported a marked increased in the runoff response under very wet conditions (snowmelt) but no significant change in response to light or moderate rain storms.

Effects on fish habitat resulting from development-related changes in the hydrological characteristics of a watershed include:

1. sedimentation of spawning habitat and pools,

2. scour of spawning and rearing habitat at peak flows, and

3. decreased base-flow resulting from reduced infiltration and lowering of the water table.

These effects may be mitigated by installing runoff controls as part of the development. A wide variety of methods are available to temporarily retain or dispose of urban runoff with a minimal impact on fish habitat. A number of techniques are described in some detail by Tonelli (1977), Fisheries and Marine Service (1978), and Scarborough Works Department (1979).

The best techniques (from a fish habitat perspective) are those which permit as much of the runoff water as possible to enter the soil moisture and ground water components of the basin; it is in this manner that the runoff water will aid in maintaining base-flows suitable for fish habitat. For this reason, the devices which dissipate storm water rather than temporarily store it are preferred. Some of these devices are settling ponds with permeable bottoms, perforated storm sewer pipe in a gravel-filled trench, 'soak-aways', dry wells, bottomless catch basins, porous asphalt-concrete pavements in roads

or parking lots and storm sewer designs which will direct flow from impermeable surfaces into permeable swales. These methods are described in some detail by Poertner (1974), Fisheries and Marine Service (1978), and Scarborough Works Department (1979).

When disposal of runoff water by infiltration is impractical, alternative methods of temporary storage should be employed to reduce the impact of accelerated runoff on fish populations. Fisheries and Marine Service (1978) reviews some of the available literature and suggests use of surface detention ponds, temporary use of recreational areas or parking lots constructed in shallow depresssions, roof-top storage, or construction of underground tanks. The practical applicability of many of these techniques to Newfoundland is unknown at this time, but obviously the underground facilities would have greater initial cost that would surface structures. However, if space is at a premium they may be necessary in some instances. All these facilities would require regular maintenance to remove accumulated silt and fine gravel. Under most circumstances natural ponds which normally provide fish should not be used for this purpose.

Whatever design is followed, the storage system should be able to contain at least the 1 in 5 year storm from the entire impervious area (include building roofs, roads and parking facilities in the calculation). Controlled release from the storage area should approximate natural runoff from the area prior to development. The release of water from storage tanks may be controlled by a variety of valves, some of which are manual and other automatically operated. Control systems which require as little as possible manual control and which are least likely to be affected by debris are recommended. Some general types which are available include constriction valves, float controls and vortex valves.

Water Quality

Water quality problems in urban areas can be divided into two major categories, point source and non-point source. Point source problems are usually relatively obvious and clean-up or ameliorative measures are straight forward. Most of the point source problems such as sewage or industrial effluent can be solved in installing appropriate treatment facilities as has already been described in the guidelines. However destruction of fish habitat by sedimentation warrants further discussion.

The deleterious effects of silt on fish and fish habitat have been well documented (Cordone and Kelley 1961; Hynes 1970; Hansen 1971; Ritchie 1972; Shapley and Bishop 1965; Murphy et al. 1981). The direct effect of silt on fish is apparently governed to some extent by the size and type of silt particles and by the species of fish present (Cordone and Kelley 1961; Alabaster 1972) but very high sustained concentrations of silt (>90 mg/L) are required before significant mortalities occur. Reduced growth, however, is apparent at much lower concentrations of suspended solids (Alabaster 1972) possibly due to reduced feeding efficiency. In most Newfoundland streams, outside urbanized areas, sustained high turbidities are relatively rare, hence severe impact from the direct effect of silt is unlikely. However, within

large urban centres, the frequency of siltation in streams appears to be increasing.

The indirect effect of silt on fish as a result of habitat degradation is a more real problem in our area. The amount of silt transported by an undisturbed stream is in an equilibrium state governed by various hydrological forces (Leopold 1968; Hanses 1971; Milhous and Klingman 1973; Virmani et al. 1973). When additional sediment enters a stream as a result of disturbance and erosion on the watershed, the sediment transport balance is affected and silt is deposited on the streambed. The site of deposition is governed by depth and velocity of the stream but silt generally accumulates in pools during low discharges and in riffles during high discharges (Keller 1978).

Silt accumulation in pools reduces the amount of habitat available for stream resident fish when flows are low and the deeper habitat is especially critical. Silt accumulation in riffle areas at higher flows may adversely affect survival of trout eggs, alevins and the aquatic invertebrates upon which the fish feed. Trout species select spawning areas where gravel permeability is high, most frequently at the head of a riffle (Stuart 1953; Webster 1981). An accumulation of silt or fine sand in these spawning areas will either prevent trout from attempting to spawn (Alabster 1972) or, if spawning has already occurred, cause a much lower survival of eggs and fry (Hausle and Coble 1976; Webster 1981).

Mitigation of the effects of suspended solids in water soil are best performed at the site of origin, i.e. by preventing soil from entering a watercourse in the first place. Point source urban sedimentation problems are most frequently associated with construction activities, therefore proper planning is very important in the prevention of severe erosin as has been stressed by Dallaire (1976) and Ferguson (1978). Some characteristics of a site which must be considered are angle of slope, length of slope soil type, soil stability, rainfall and runoff data for the construction period, presence of temporary or poorly defined watercourses, and presence of bogs or wetlands and presence of streams which provide fish habitat. The types of sediment control programs are as many and varied as are construction sites (Thronson 1971; Meyer et al. 1972; Dove 1974; Dallaire 1976; Dane 1978a, Ferguson 1978) but can generally be divided into permanent and temporary measures (Table 4). If an appropriate sediment control plan is instituted, the impact of sedimentation on fish habitat should be reduced to an acceptable level.

Water quality problems arising from general urban runoff are not usually as obvious as point-source problems but studies have revealed considerable increases in a wide variety of pollutants as a result of non-point--source urban runoff (Colston 1974). Most of these pollutants are associated with suspended solid particles, hence treatment to remove suspended solids will solve most of the problem. Suspended particles may be removed from runoff by either: (1) settling (either simple or flocculent-assistant) or (2) the use of mechanical separators.

Whenever possible, settling basins should be constructed between the main storm sewer and the receiving watercourse. A simple design for an effective settling basin has been presented by Yrganainen (1975). The basin (see

Table 4. Sedimentation and erosion control measures useful in urban developments.

Treatment Practice	Description	Comments
Temporary measures (for sedimentation control during construction)		
Construction timing	Construction projects on sites where erosion and sedimentation are likely should be scheduled for the time of year when rainfall is usually lowest.	The clearing and grubbing of sites should be performed in summer, when high rainfall is least likely.
Limit area of exposure	Natural vegetation and organic topsoil should be removed from a minimum of a construction site.	
Limit time of exposure	Sites should not be cleared and grubbed until actual construction is ready to begin.	
Runoff diversion	A stabilized channel or a perforated subdrain should be constructed upslope of the construction site to intercept surface runoff and soil through-flow before it reaches the construction site.	Interception of water upslope of a construction site will greatly reduce rill flow and gullying on the site. Note: Permanent watercourses which provide fish habitat should not be diverted in this manner.

Table 4 (Cont'd.)

Treatment Practice	Description	Comments
Checkdams or diversion terraces	Checkdams or diversion terraces should be constructed at intervals across a sloped construction site to slow the rate of runoff down the slope, to retard erosion and permit silt to settle out.	These dams or barriers may be constructed of permeable gravel, sandbags, brush, gabions, or commercial filter fabric. Another acceptable alternative would be to leave naturally vegetated strips. Diversion terraces should be lined with rip rap or plastic sheet to minimize erosion.
Sediment barriers	Sediment barriers consisting of permeable gravel berms, gabions, brush barriers, or silt fences may be used to trap sediment from smaller constructions sites.	These barriers permit water to percolate through but slow the flow to permit much of the silt to 'settle out'. They may be installed at the downslope of the site or at the inflow to existing storm sewer facilities.
Sediment basins	Sediment basins should be constructed for all larger sites where siltation is a potential problem.	Designs for sediment basins may be found in Thronson (1971); Yrganainen (1975); Dallaire (1976); and Fisheries and Marine Service (1978).
Mulches	Mulches consisting of wood chips, stone, glass fiber, cement, crushed stone, or commercial anti-erosion mats may be used to limit erosion on land which has been cleared of vegetative cover.	The mulches protect bare soil from the erosive effects of wind and rain and aid in reestablishing vegetative cover.

Table 4 (Cont'd.)

Treatment Practice	Description	Comments
Scarification	By leaving a rough surface on the construction site, runoff velocities and erosion are reduced.	This can easily be performed on a daily basis prior to a work stoppage.
Permanent measures (for sedimentation control subsequent to construction)		
Sediment basins or separators	Permanent sediment basins or hydraulic particle separators should be installed to remove sediment from runoff before it is discharged into fish habitat.	Designs for these devices are presented by Thronson (1971), Yrganainen (1975), Tonelli (1977) and Fisheries and Marine Service (1978). Some of these designs also remove oil or other floating debris.
Seeding or sodding	Seed or sod should be used to reestablish vegetation on all areas not otherwise stabilized by gravel or pavement.	Seed may be spread on steeper slopes and rough terrain by means of a hydro seeder. On some instances a biodegradable mulch should be used in conjunction with seed to protect the soil until the grass is established.
Stabilization of slopes and diversion channels	Steep slopes and diversion channels should be stabilized with rip rap to prevent sediment from being washed into fish habitat.	

Fig. 12) is a rectangular structure with length = 4 X width and having the inlet and outlet at opposite ends. The surface area required for this sediment basin design was based on the settling rate of a mean silt particle (0.0275 mm) the amount of time required for the water to move the length of the sediment basin, and the runoff anticipated from a yearly maximum storm. The settling rate of the mean silt particle is 0.0675 cm/s. Runoff anticipated from a yearly maximum storm may be computed from the equation Q = CIA where:

C = runoff coefficient of the developed area,

I = maximum rainfall intensity, and

A = area of development.

The surface area of the basin required to remove average silt-sized particles is compiled by equating the settling velocity of the mean silt particle (Vs) to the velocity of low through the basin using peaking inflow from a one-year storm:

$$Vs = Vf.$$

$$Vs = \frac{\text{Qmax, one-year storm}}{\text{surface area of basin (Ab.)}}$$

$$Ab = \frac{Qmax}{Vs}$$

if peak inflow is assumed to be 1 m^3/s then:

$$Ab = \frac{1\ m^3/s}{Vs} = \frac{1\ m^3/s}{0.0675\ cm/s} = 1481.5\ m^2$$

Therefore, for an anticipated runoff of 1 m^3/s, a basin with a surface area of 1481.5 m^2 would be required. Higher anticipated runoff would require correspondingly larger settling basins. The above design will remove sediment particles 0.0275 mm and larger from the storm water provided the designed flow rates are not exceeded. To accommodate extra heavy rainfall, inflow and outflow control structures may be necessary. Alternative settling pond designs are described by Thronson (1971), Tonelli (1977), and Fisheries and Marine Service (1978). Most of the impurities resulting from a storm in an urbanized area are carried by the first flush of runoff water (Tonelli 1977); therefore, a system of flow control valves could be incorporated such that the initial highly polluted runoff would enter the settling pond, and later cleaner water could bypass the treatment. This design approach could minimize overall cost by reducing the capacity of the settling pond below that which would be required for a five-year or 25-year storm. The actions of settling ponds may be enchanced through additions of a flocculating agent such as alum to the influent water (Colston 1974), but this will only be necessary in an area where very small particles (e.g. clays) are an imporant constituent of the total suspended load.

In areas where settling ponds prove impractical, they may be replaced by suitable mechanical or hydraulic separators which remove suspended material from solution (Tonelli 1977). However, all of these devices must be designed with a suitable holding or settling facility to retain the material removed from the storm sewer effluent for suitable disposal.

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